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Environmental Assessment of Surface Mining Methods: Head-of-Hollow Fill and Mountaintop Removal. Volume 1

Skelly and Loy, Harrisburg, PA

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ENVIRONMENTAL ASSESSMENT OF SURFACE MINING METHODS: HEAD-OF-HOLLOW FILL AND MOUNTAINTOP REMOVAL

VOLUME 1

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This study was undertaken to assess the environmental effects of coal mining and reclamation techniques employed in Kentucky and West Virginia mountaintop removal and head-of-hollow fill construction. The endeavor was divided into four phases:

I. State-of-the-Art Review
II. General Environmental Assessment of Ten Kentucky and West Virginia Coal Mine Sites
III. Intensive Mine Site Monitoring andEnvironmental Assessment in Both States
IV. Evaluation and Update of Hollow Fill Construction Guidelines

The results of Phase I, II, and IV were reported in an interim report (EPA-600/7-79-062) published in July 1979. Phase III results are reported in this document.

Phase III work consisted of a detailed environmental assessment conducted at two surface coal mine sites in Kentucky and West Virginia, including study of rainfall/runoff relationships, water quality, stream benthic macroinvertebrate community, and terrestrial vegetation. Also included was an introductory investigation into head-of-hollow fill stability and a study of fugitive dust emissions generated by Appalachian coal mines. A more detailed analysis of fill stability also completed under this contrace appears in a separate report (Volume 2).

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory - Cincinnati (IERL-CI) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This study details the results of an environmental assessment of head-of-hollow fill and mountaintop removal coal mining methods. This subject has been under study by the Energy Pollution Control Division of the Industrial Environmental Research Laboratory, which may be contacted for further information.

David G. Stephan
Director
Industrial Environmental Research Laboratory
Cincinnati

ABSTRACT

This study was undertaken to assess the environmental effects of coal mining and reclamation techniques employed in Kentucky and West Virginia mountaintop removal and head-of-hollow fill construction. The endeavor was divided into four phases:

I. State-of-the-Art Review

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Phase III work consisted of a detailed environmental assessment conducted at two surface coal mine sites in Kentucky and West Virginia, including study of rainfall/runoff relationships, water quality, stream benthic macroinvertebrate community, and terrestrial vegetation. Also included was an introductory investigation into head-of-hollow fill stability and a study of fugitive dust emissions generated by Appalachian coal mines. A more detailed analysis of fill stability also completed under this contract appears in a separate report (Volume 2).

This report was submitted in partial fulfillment of Contract Number 68-03-2356 by Skelly and Loy under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period November 4, 1975 to April 30, 1980 and work was completed as of April 30, 1980.

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SECTION 1
INTRODUCTION

Coal mining within the United States has been the subject of intense debate among private individuals, environmental groups, government officials, and industry representatives in recent years. A critical focus of this debate has been the effects of mining on the immediate environment. By disturbing the natural state of a watershed in order to remove coal, are we causing irreparable harm to the ecosystem, or are we maintaining a balance between our need for more energy and our desire to live in harmony with the environment?

Until 1967, surface mining in the steep-sloped Appalachian terrain was limited to conventional contour stripping using downslope spoil disposal. Use of this method allowed the exposed spoil to weather and erode, contributing sediment, acid and other toxic material to adjacent streams. In 1967, a new method of mining, mountaintop removal, was first employed at a large surface mine in West Virginia. Rather than disposing of spoil downslope, as was done in previous contour stripping operations, the excess spoil material was placed in specific disposal areas known as head-of-hollow or valley fills. Use of this technique allowed surface mining of coal for maximum recovery with a minimum of disturbed area and environmental degradation.

Despite the fact that head-of-hollow fill and mountaintop removal methods have been used in Appalachia since 1967, their environmental effects had not been investigated in detail. This project, "Environmental Assessment of Surface Mining Methods: Head-of-Hollow Fill and Mountaintop Removal," attempted to determine these effects through a four phase effort. Phase I encompassed a review of the current state of the art of mountaintop removal mining. Phase II consisted of a general environmental assessment of ten mining operations in Kentucky and West Virginia that employed head-of-hollow fill construction and mountaintop removal, Phase III was an intensive environmental assessment of two mine sites, one in each state. Phase IV consisted of an evalulation of hollow fill construction guidelines, based on findings in Phase II. An interim report (EPA-600/7-79-062) published previously (July 1979) presented the findings of Phases I, II, and IV. Volume I of this report contains the findings of Phase III and Volume II contains the results of the analysis of the long-term stability of valley fills.

The environmental effects of the different methods of hollow fill construction practiced in Kentucky and West Virginia, as dictated by respective state regulations, were perceived to be of greater importance in this assessment than were any differences attributed to the mining technique itself. Therefore, site selection for Phase II was based on availability of mine sites with several associated head-of-hollow fills, preferably but not necessarily mined through mountaintop removal. Although the site selected in West Virginia (WV-07-SA) was a mountaintop removal operation, no site using this method of mining with a suitable time frame and willingness to participate could be located in Kentucky. Consequently, the site selected in Kentucky (KY-07-LA) was a contour strip operation.

For a period of three years each site was monitored to record changes in the rainfall-runoff relationship, water quality, and stream benthic macroinvertebrate community. The wildflower and woody species present at selected areas of each site were studied to describe the vegetation present prior to disturbance by mining.

A program of drilling and soil sampling of selected head-of-hollow fills, including the one present at Site KY-07-LA, was conducted to determine in-place characteristics of constituent fill material. This investigation was introductory to a later, more detailed study intended to provide data relating subsurface conditions to long-term fill slope stability. The results of the more detailed study are presented in Volume II.

Another component of this environmental assessment of surface coal mining was the study of fugitive dust emissions. Various mining activities on several mines in the Appalachian region were monitored to collect data to prepare estimates of rates of dust emission.

SECTION 2
CONCLUSIONS

MINE SITE ENVIRONMENTAL ASSESSMENTS

Prior to enactment of the federal surface mining law, Kentucky requirements for excess overburden storage allowed for downslope disposal of mining spoil. Employment of downslope disposal in construction of head-of-hollow or valley fills prevented concurrent revegetation to stabilize exposed surface areas and led to the construction of long uninterrupted outslopes, both contributing to erosion of the fill surface.

From rainfall/runoff relationships measured at Intensive Site KY-07-LA, rainfall events occurring after mining began produced approximately five percent more runoff than events prior to mining.

The quality of water leaving the mine area deteriorated following initiation of mining, as exhibited by an increase in acid properties and suspended load. Following the end of mining, the water was less acid, but carried even more suspended load. Passage of the water through the sedimentation pond did not appear to remove suspended load during mining. However, the pond was much more effective in such removal following the end of mining.

It is difficult to determine whether cessation of surface mining activity in the watershed had a significant positive impact on this stream's macroinvertebrate community. The number of taxa collected during the period of active mining (31) was higher than the number collected after mining had ceased (13). However, both collections included mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera), groups traditionally considered pollution sensitive.

The West Virginia method of head-of-hollow or valley fill construction appeared to lead to more stable slopes relative to erosion potential. Because of the hauldown method of staged fill construction, the outslope or face of the fill may be revegetated prior to the end of construction. Additionally, the use of terraces reduces the length of uninterrupted outslopes susceptible to erosion. For these reasons, no erosion scars of the magnitude present on the Kentucky fills were observed at the West Virginia site.

Changes in quality of water after initiation of mining were evident in weekly composite sample measurements made upstream of the sedimentation pond. As would be expected, pH dropped slightly, and turbidity, total solids, total iron, and sulfate increased. Monthly composite samples indicated that conductivity, calcium, magnesium, and aluminum also increased while the trace metals copper, zinc, cadmium, and nickel remained nearly the same or declined.

Comparison of values measured above (influent) and below (effluent) the sedimentation pond allowed approximation of its efficiency as an instrument of water quality improvement during active mining. Turbidity and total solids were substantially reduced in the water by its passage through the pond. Total iron, aluminum, and copper also decreased. However, conductivity, sulfate, calcium, and magnesium increased.

Here again, it is difficult to conclude if surface mining had an adverse impact on the stream's benthic macroinvertebrate community. Although fewer macroinvertebrate species were collected in the stream after initiation of mining, those species present were not nuisance species. They included groups traditionally considered sensitive to environmental perturbation, mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera). Furthermore, macroinvertebrate numerical densities increased after mining began. It must be noted, too, that the structure of macroinvertebrate communities is inherently dynamic and not well understood. What may be loosely interpreted as community change due to adverse impact may, in fact, be in response to unrecognized stimuli.

VALLEY FILL SUBSURFACE INVESTIGATIONS

The three fills investigated as part of this study were composed of dense material which had not suffered substantial degradation. The groundwater information indicated that the fills were free draining and that no water was ponding within the fills. The natural moisture content of the fill material was that expected for coarse grained material or the natural bedrock from which it was derived. Although no detailed analyses were performed on the geometry of the fills, the material comprising the fills, and the natural overburden conditions led us to conclude that the fills were stable.

FUGITIVE DUST EMISSIONS INVESTIGATION

The study of fugitive dust emissions by high volume sampling revealed large variation among individual samples, both spatially and temporally. Haul road traffic provided the greatest dust emission. At one mine, drilling, overburden removal, and coal loading monitored as a joint operation was nearly as dust-producing as haul road traffic, with regrading a distant third. At two other mines, emissions from drilling, overburden removal, and coal loading and from regrading were similar, with those from haul roads somewhat higher. Fugitive dust on reclaimed areas at all three mines was nearly identical and quite low relative to that measured near active mining operations. Both mountaintop removal mines investigated in this segment of the study were greatly different in measured densities of fugitive dust emissions. The contour mine was intermediate and displayed measured densities similar to those observed at the less dust-producing mountaintop removal mine.

The study of dustfall also revealed large spatial and temporal variation among individual samples. No inverse relationship between source-receptor distance and mass of dustfall was observed. There was no large difference in mass of dustfall between the mountaintop removal and contour mines.

It would appear that if similar machinery is used in both mining techniques, as it was at the mines monitored, differences in fugitive dust emissions are the result of local soil types and meteorological conditions, rather than the result of mining technique.

SECTION 3
RECOMMENDATIONS

The recommendations contained in this section are restricted to those derived from work conducted in Phase III of the project, involving intensive monitoring and environmental assessment of two mine sites in Kentucky and West Virginia. Recommendations from other phases were contained in the interim report published in July 1979.

The results of the stream water quality and benthic macroinvertebrate investigations showed no distinct trends from which firm conclusions could be drawn. Undoubtedly this is due in part to the small number (two) of sites studied. Similar efforts conducted at additional locations may allow recognition of a pattern in results. Furthermore, it is recommended that qualitative rather than quantitative macroinvertebrate samples be collected at sample stations on at least a quarterly basis. Qualitative techniques would allow sample collection efforts in pools and on large particle substrates (boulders, bedrock, etc.) where quantitative sampling employing the Surber Sampler is virtually impossible. Sampling on at least a quarterly basis would provide sufficient samples to describe seasonal changes in macroinvertebrate community structure, possibly indicating particular times of the year when the community might be more susceptible to mining impact.

During the course of the investigation, certain difficulties related to the stream water quality programs became apparent. Automatic samplers that removed and stored water samples at pre-determined intervals were poorly suited to the environment in which they were placed. Occasional failure of storage batteries to hold charges sufficient to maintain sampler operation and freezing of water conduction lines were attributed to low temperatures encountered in winter. Furthermore, automatic samplers in place along streams were observed to be susceptible to damage resulting from flooding occurring during periods of heavy rainfall. It is recommended that grab water sample collection by a field technician be employed on mine site streams, rather than unattended long-term use of automatic water samplers.

With regard to the assessments of fugitive dust, large variations in dust emissions were observed among the four mines studied. Furthermore, no trends in emissions among different mining unit operations were recognized. Collection of additional data at other locations may allow preparation of more precise emission rates and factors for mining activities in the Appalachia area.

SECTION 4
EASTERN KENTUCKY MINE SITE

PHYSICAL DESCRIPTION OF THE EASTERN KENTUCKY STUDY REGION

The descriptions of topography, climatology, geology and soils, hydrology and land use were excerpted from Andersen (1959). References for the vegetation and wildlife sections are Kuchler (1964), Clay (1975), Conant (1975), Burt (1975) and Petersen (1947).

Topography

Gradually sloping in a westerly direction, the rugged Cumberland Plateau of eastern Kentucky contains approximately 27,195 square kilometers (10,500 square miles), or roughly one-fourth of the total land in the state. Through geological history, three principal rivers, the Cumberland, the Big Sandy, and the Kentucky, along with their large tributaries, have transformed the region into an area of long narrow valleys and steep ridges.

The parallel Pine and Cumberland Mountain Ranges in the southeast, carved from the upturned edges of hard sandstone, meet at their extreme termini to form the Middlesboro Basin. The basin contains two additional minor ranges, the Little and Big Black Mountain Ranges. It is here that the highest mountain in the State is found, Big Black Mountain, with an elevation of approximately 1,265 meters (4,150 feet) above sea level. The general altitude of the adjacent Cumberland Plateau is approximately 610 meters (2,000 feet) above sea level and slopes westwardly reaching the Interior Low Plateaus where the elevation ranges from 76 to 122 meters (250 to 400 feet) above sea level.

Climatology

Moderate best describes eastern Kentucky's climate. The mean annual temperature is around 16°C (60°F); average midsummer temperatures range between 24°C and 27°C (75° - 80°F). The mean minimum and maximum temperatures for July range from 16° - 20°C (62° - 68°F) and 30° - 33°C (86° - 92°F), respectively. The daily average midwinter temperature is approximately 2°C to 3°C (36° - 40°F) with nights sometimes considerably colder. The mean minimum and maximum temperatures for January range from -4° - -1°C (24° - 30°F) and 5° - 10°C (41° - 50°F) respectively. Temperatures in excess of 38°C (100°F) and below - 18°C (0°F) occur with a frequency of about once a year, although record temperatures ranging from 46°C (114°F) to low of -34°C (-30°F) have been recorded.

Frost-free days on the Cumberland Plateau range from 160 to 180 in the central area, and 180 to 200 on the peripheral edges. The first killing frost usually occurs between October 13th and 21st, and the last between April 18th and 23rd. Thus, the average growing season ranges from 174 to 189 days.

Annual rainfall is usually 97 to 102 centimeters (38 - 40 inches), with approximately 51 centimeters (20 inches) of snow falling on the plateau in the winter. The average number of rainy days is about 118 a year with the autumn months generally the driest. Rainy and snowy days are 30% - 50% more frequent in the months from December to August.

Approximately 40 to 50 thunderstorms occur per year, with less than six tornadoes per decade. Days are sunny a minimum of 52% of the year.

Winds in eastern Kentucky are similar to those in the rest of the state. Summer winds prevail from the south and southwest, and winter winds generally are from the north and northwest.

Geology and Soils

The geologic divisions of the Cumberland Plateau are almost entirely of the Pennsylvanian System, composed of interbedded sandstones, siltstones, shales, and coals. Older Mississippian formations are found in the valley floors, and limestones characteristic of the Ordovician contribute greatly to the fertility of the soils. However, these Ordovician limestone deposits do not become a dominant feature until the Cumberland Plateau tapers off into the central portion of Kentucky known as the Bluegrass region, which lies adjacent to this study area.

The soils found in the valleys, the primary urban and agricultural areas, are generally flood plain soils such as Pope and Cuba. On the stream terraces and 1/2 to 2/3 of the way up the sides of the ridges, colluvial soils such as Allegheny and acidic Shelocta types are found. The upper ridge slopes are covered primarily with denser, acidic clay-shale soils, and are of a much more shallow depth than the alkaline alluvial valley soils.

Hydrology

Four major rivers drain the interior of the Cumberland Plateau: the Cumberland, Kentucky, Big Sandy, and Licking Rivers (for a summary of hydrologic data, refer to Table 1). Only the Kentucky River has the necessary depth to be considered a navigable inland waterway by the U.S. Water Resources Council.

The Kentucky, Big Sandy, and Licking Rivers are part of the Ohio River Drainage Basin; the Cumberland River is incorporated into the Tennessee-Cumberland Drainage Basin.

TABLE 1. HYDROLOGIC DATA - KENTUCKY STUDY REGION

RIVER	GAUGING STATION	DRAINAGE AREA (km^2)	AVERAGE DISCHARGE (m^3/s)	EXTREME DISCHARGE (m^3/s) HIGH	LOW
Kentucky	Heidelberg	6,881,625	163.5	2,282.3	5.6
Cumberland	Rowena	14,996,088	384.5	1,180.8	3.1
Big Sandy	Louisa	10,080,272	202.8	1,633.9	19.0
Licking	Catawba	8,546,993	175.4	1,475.3	5.7

NOTE: The flows of the Kentucky, Cumberland, and Licking Rivers are regulated by locks and dams. The Big Sandy River is only partially regulated.

Groundwater aquifers are extensive in the Cumberland Plateau, and a major consolidated aquifer (composed of cavernous limestones) passes through almost 50% of the plateau. Such aquifers are capable of yielding hundreds of gallons of water per minute to individual wells.

Land Use

Terrain limits the land use in eastern Kentucky. Most industrial, urban, and agricultural areas are contained within the stream and river valleys. Commercial coal mining (a major industry), and general farming operations utilize available slope and ridge areas. "Unused" land remains as forest, composed usually of second growth hickory and oak, some of which is utilized by a modest timbering industry. Natural gas and petroleum production are other important industries, with the Big Sandy gas fields responsible for over 90% of the state's annual production.

Major transportation facilities include Interstates 75 and 64, as well as the east-west Mountain and Daniel Boone Parkways. Due to the topography of the land, numerous north-south state highways exist throughout the Cumberland Plateau study area.

Vegetation and Wildlife

The deciduous forest biome of the Cumberland Plateau is characterized by the most varied plant and animal life in Kentucky. Dominant hardwood species include oak, hickory, maple, and poplar. Conifers such as the Virginia pine are found in isolated stands throughout the region. In the river valleys the Kentucky coffee tree, magnolia, wild plum, and crab apple also occur. Typical understory species include laurel, huckleberry, and rhododendron; wildflowers include lady slipper, trillium, violet and bluebell.

The forest supports diverse mammal and bird communities. Native mammals include the eastern gray squirrel, white-tailed deer, rabbit, chipmunk, and opposum. Major mammalian predators are the mink, skunk, raccoon, and fox. Quail, ruffed grouse, wild turkey, and mourning dove are the principal game birds. Song birds include the bluebird, cardinal, mockingbird, and yellow warbler.

Although some isolated mountain streams contain good populations of trout, warm water fish dominate the main creeks and rivers. Species include the walleyed pike, bluegill, smallmouth bass, muskellunge, white-sucker, channel catfish, and white perch.

Three species of poisonous snakes are found: the timber rattlesnake, copperhead, and cottonmouth. Numerous harmless varieties inhabit the region.

GENERAL SITE DESCRIPTION

The surface mine site in eastern Kentucky chosen for more detailed monitoring (KY-07-LA) is located in Perry County (Figure 1). The watershed drains to the Middle Fork of the Kentucky River immediately downstream of Buckhorn Lake Dam. Elevations in this watershed range from 275 meters (900 feet) to 457 meters (1500 feet). The average watershed slope is 10 percent with side slopes as steep as 40 percent. Prior to mining, the watershed was undisturbed except for some nominal disturbance from exploration activities. Cover type for the watershed consists of dense forest on the steep side slopes and small meadow areas in the bottom land.

The mine plan for the area called for conventional contour stripping at a bench level of approximately 366 meters (1200 feet) to remove three splits of the Hazard #5A Seam. At the time this site was mined, Kentucky did not require backfilling of exposed highwalls. Since backfilling was not required, the majority of overburden removed from the bench level was pushed into the adjacent hollows to form hollow fills. For the disposal of excess overburden, four separate hollow fills were planned as shown in Figure 2.

Construction of the hollow fills was accomplished by the end dump and push down method. Excess overburden was hauled to the head of the hollow and dumped at bench level. The material was allowed to roll down the outslope to permit gravity separation of the different sizes of material. According to Kentucky regulations, the outslope then was downgraded to 20 degrees or less every 48 hours to provide stability for the advancing fill face. Figure 3 shows a schematic of the Kentucky method of fill construction.

Of the 65 hectares (160 acres) in this watershed, approximately 24 hectares (58 acres) or 36 percent of the watershed was to be disturbed by mining. Drainage control for the disturbed area was provided by a sedimentation pond located in the main channel of the unnamed receiving stream.

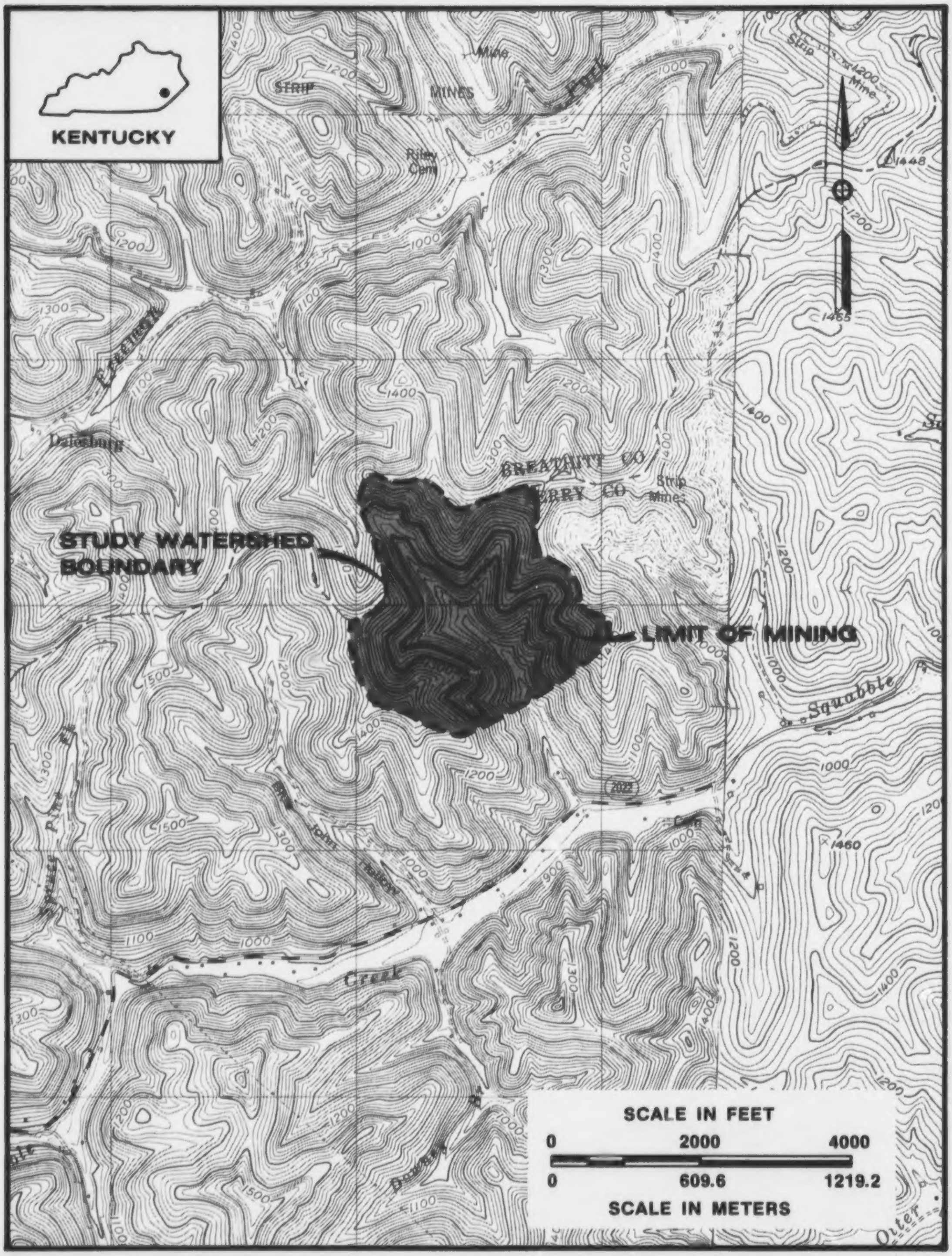

KENTUCKY
STRIP
MINES
Mine
Riley Cem
Strip Mine
1448
1465
Dalesburg
BREATHITT CO
PERRY CO
Strip Mines
STUDY WATERSHED BOUNDARY
LIMIT OF MINING
Squabble
2022
Cem
1460
Creek
SCALE IN FEET
0
2000
4000
0
609.6
1219.2
SCALE IN METERS

Figure 1. Location map - intensive site KY-07-LA.

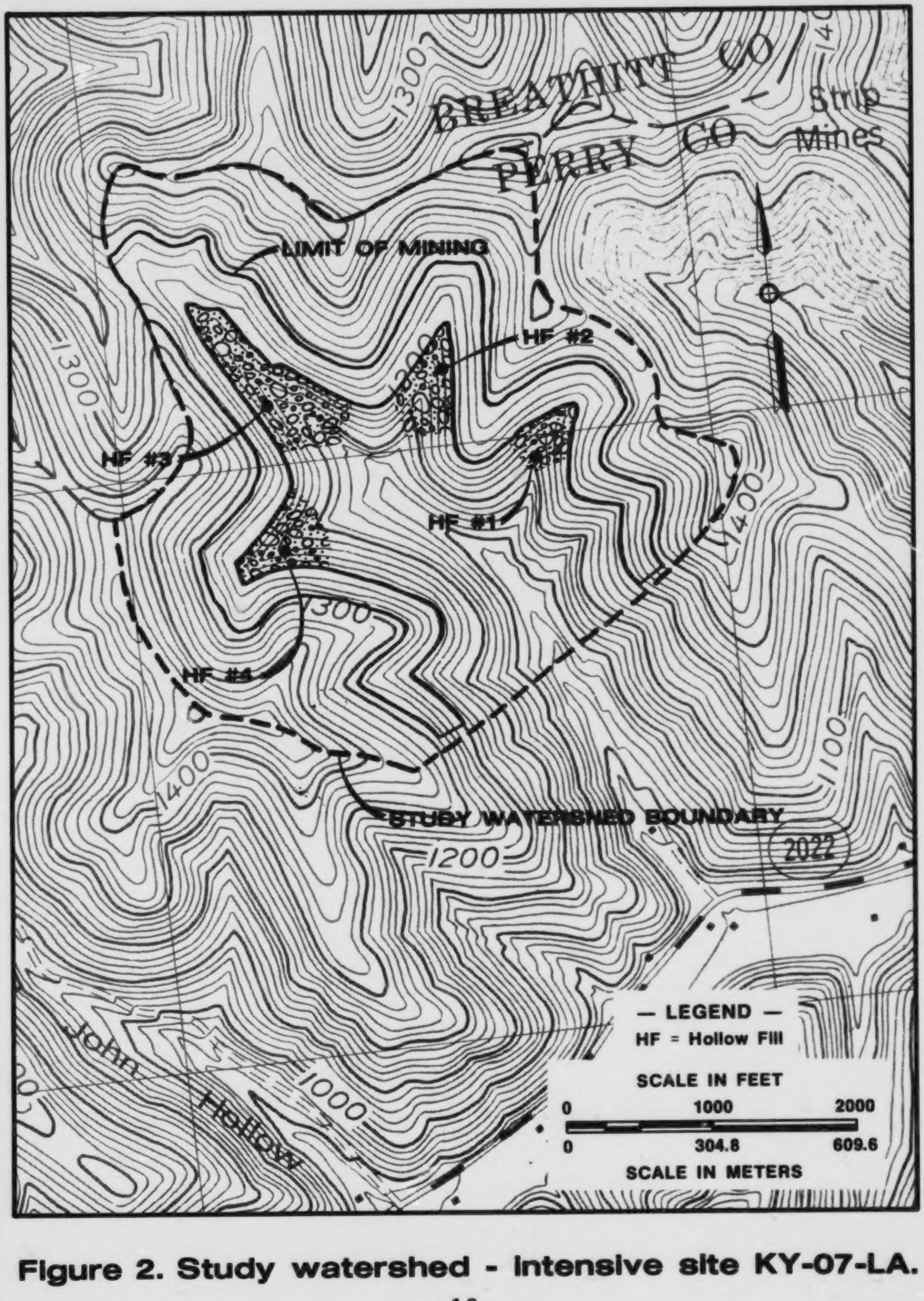
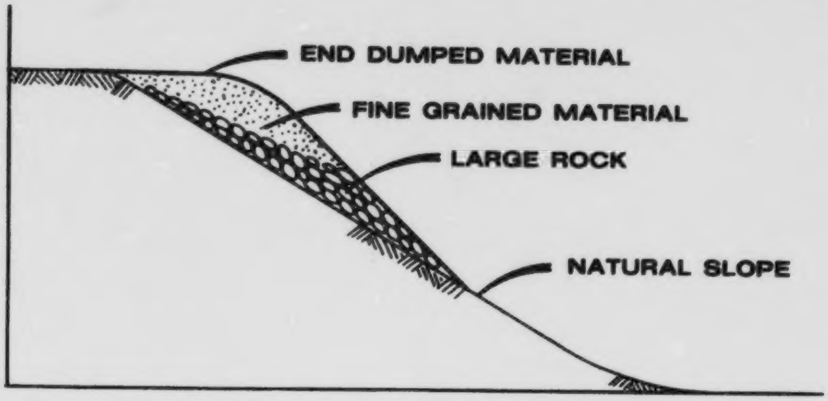
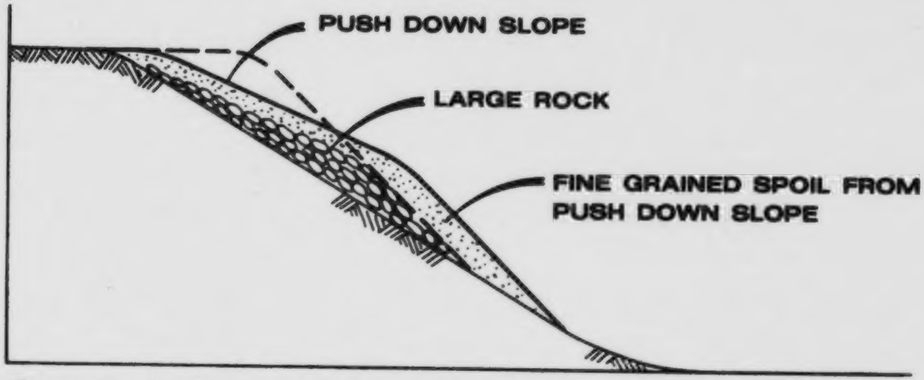

BREATHITT CO
PERRY CO
Strip Mines
LIMIT OF MINING
HF #1
HF #2
HF #3
HF #4
STUDY WATERSHED BOUNDARY
1300
1400
1200
1100
1000
2022
John Hollow
— LEGEND —
HF = Hollow Fill
SCALE IN FEET
0
1000
2000
0
304.8
609.6
SCALE IN METERS

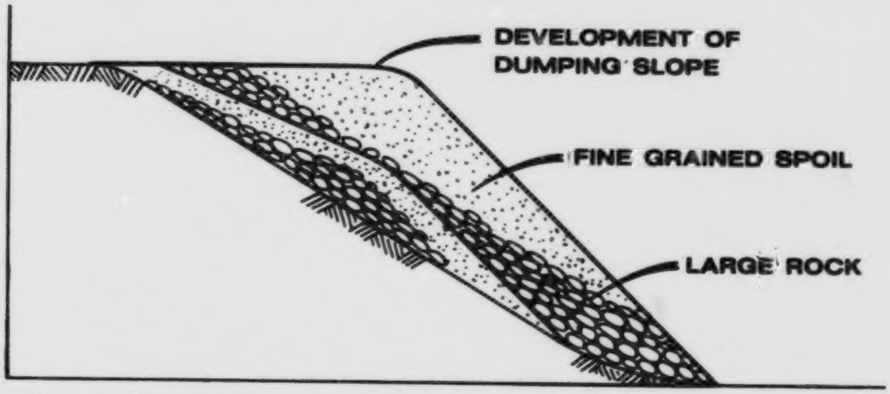
Figure 2. Study watershed - intensive site KY-07-LA.


END DUMPED MATERIAL
FINE GRAINED MATERIAL
LARGE ROCK
NATURAL SLOPE

Step 1. Beginning of Head-Of-Hollow Fill.


PUSH DOWN SLOPE
LARGE ROCK
FINE GRAINED SPOIL FROM
PUSH DOWN SLOPE

Step 2. 48 Hours Later - Spoil Is Pushed Down To 20° Slope.


DEVELOPMENT OF
DUMPING SLOPE
FINE GRAINED SPOIL
LARGE ROCK

Step 3. Progression of Kentucky Hollow Fill.

Figure 3. Sequence of Kentucky head-of-hollow fill construction.

Mining activities on this watershed began in October 1976 with clearing and grubbing operations. Work on the first hollow fill began in December and continued until March 1977. Mining in the watershed was continuous from October 1976 to June 1977 when the mined area was regraded and replanted. To document mine progression, aerial photographs of the mine site were taken on the following dates:

- November 1976
- April 1977
- July 1978
- September 1979

The first of the series of photos, November 1976 (Figure 4), shows mining just beginning near the head of the hollow with contour operations preparing to cross the drainage divide into the study watershed. The hollow fill in the head of the hollow (HF #3) was begun in December 1976 and completed in March 1977. Hollow fills HF #1 and HF #2 were also begun and completed during this time period. An aerial photograph taken of the study area in April 1977 depicts the mine progression from November 1976 to April 1977 (Figure 5). As can be seen in the photograph, hollow fills HF #1-HF #3 were completed and hollow fill HF #4 was under construction. By June 1977, mining was completed and revegetation of the disturbed area had begun. The aerial photographs taken in July 1978 and September 1979 (Figures 6 & 7) show the mine area after reclamation had been completed. Close scrutiny of these photos reveals several large gullies developed on the surface of the fills.

ENVIRONMENTAL MONITORING PROGRAM

The monitoring program for the environmental assessment of this surface mine site consisted of several phases, including:

1. Rainfall/runoff relationship;
2. Water quality;
3. Stream benthic macroinvertebrate community; and
4. Terrestrial vegetation.

Rainfall/Runoff Relationship

Surface water monitoring of this watershed began in May 1976 with the installation of a permanent surface water monitoring station to allow continuous monitoring of runoff (Figure 8). The station consisted of a 7.6 cm (3 inch) Parshall flume with a Stevens Model 61R Total Flow Meter. The flume was positioned in the center of the stream and surrounded by sand bags to direct the stream flow through the flume. The monitoring station operated until August 1977 when it was destroyed by a flash flood in the watershed. The station was reconstructed later that month using a concrete dam instead of sand bags. Figure 9 is a photograph of the monitoring station showing the concrete dam, Parshall flume, Stevens Total Flow Meter, and ISCO Water Sampler. Figure 10 is a drawing showing details of the station construction. An attempt was made to monitor surface water flows continuously from May 1976 to August 1978 to provide data on pre-mining, mining, and post-mining conditions.

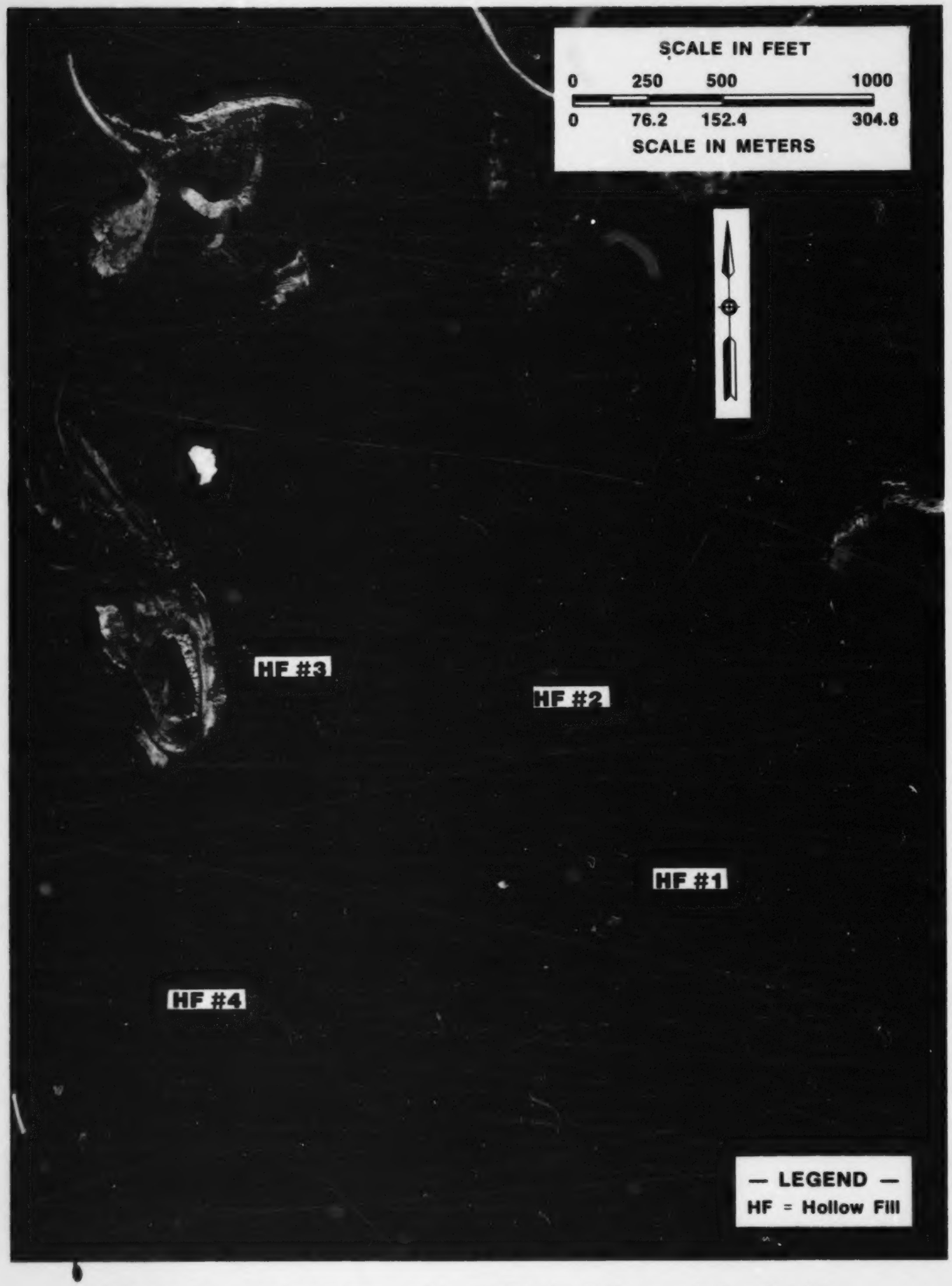

SCALE IN FEET
0
250
500
1000
0
76.2
152.4
304.8
SCALE IN METERS
HF #3
HF #2
HF #1
HF #4
— LEGEND —
HF = Hollow Fill

Figure 4. Intensive site KY-07-LA aerial photo - Nov. 1976.

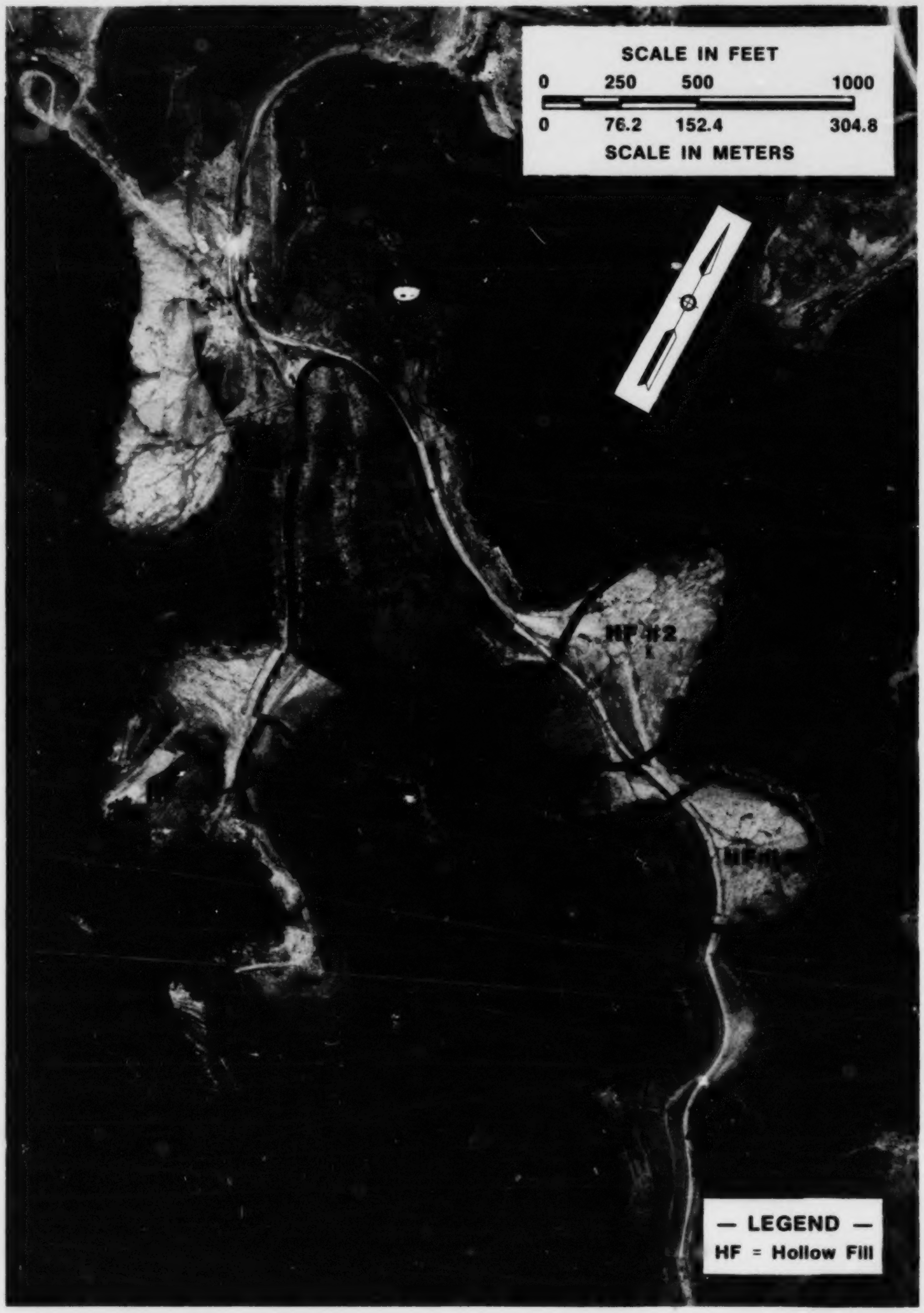

SCALE IN FEET
0
250
500
1000
0
76.2
152.4
304.8
SCALE IN METERS
HF #2
HF #1
— LEGEND —
HF = Hollow Fill

Figure 5. Intensive site KY-07-LA aerial photo - April 1977.

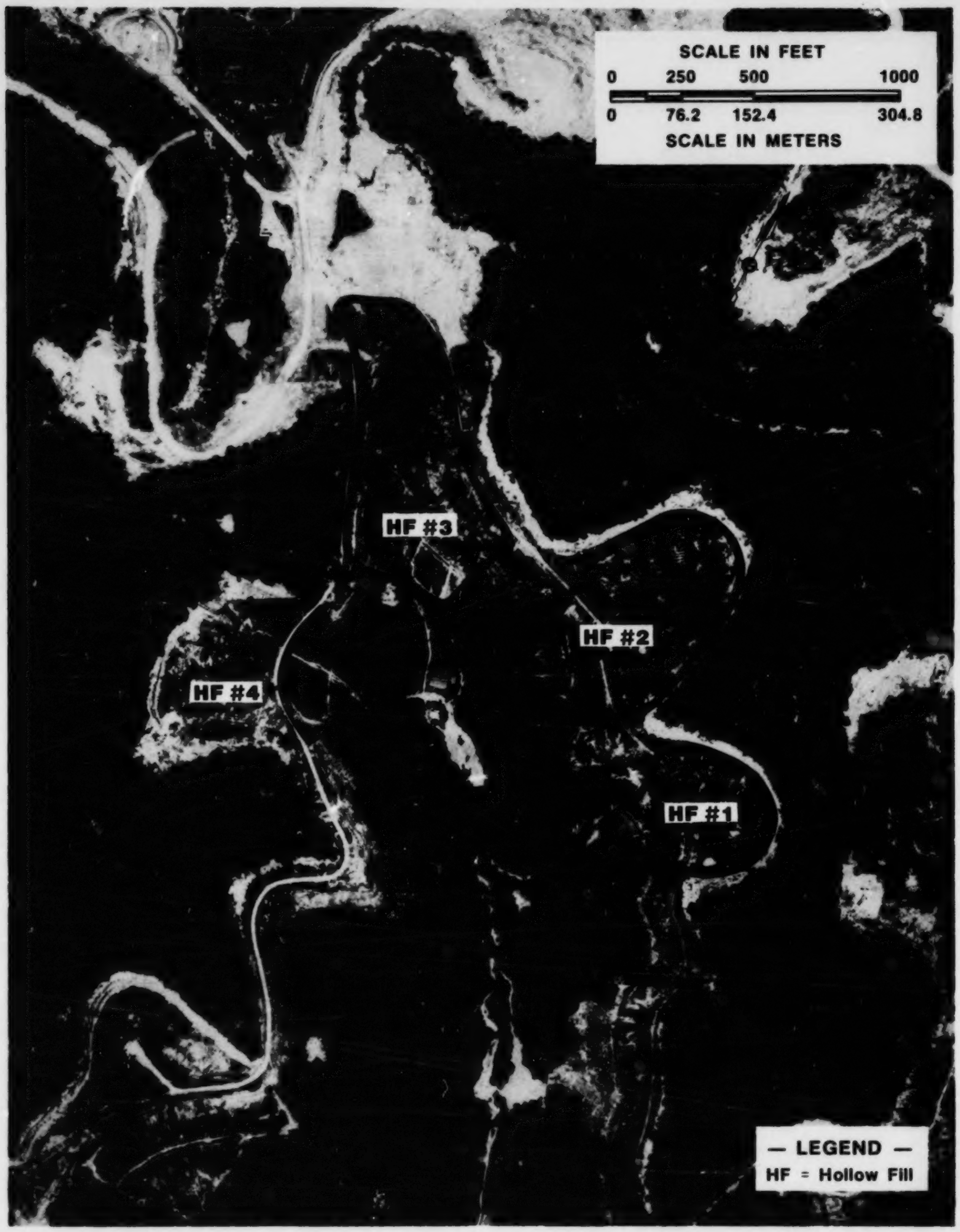
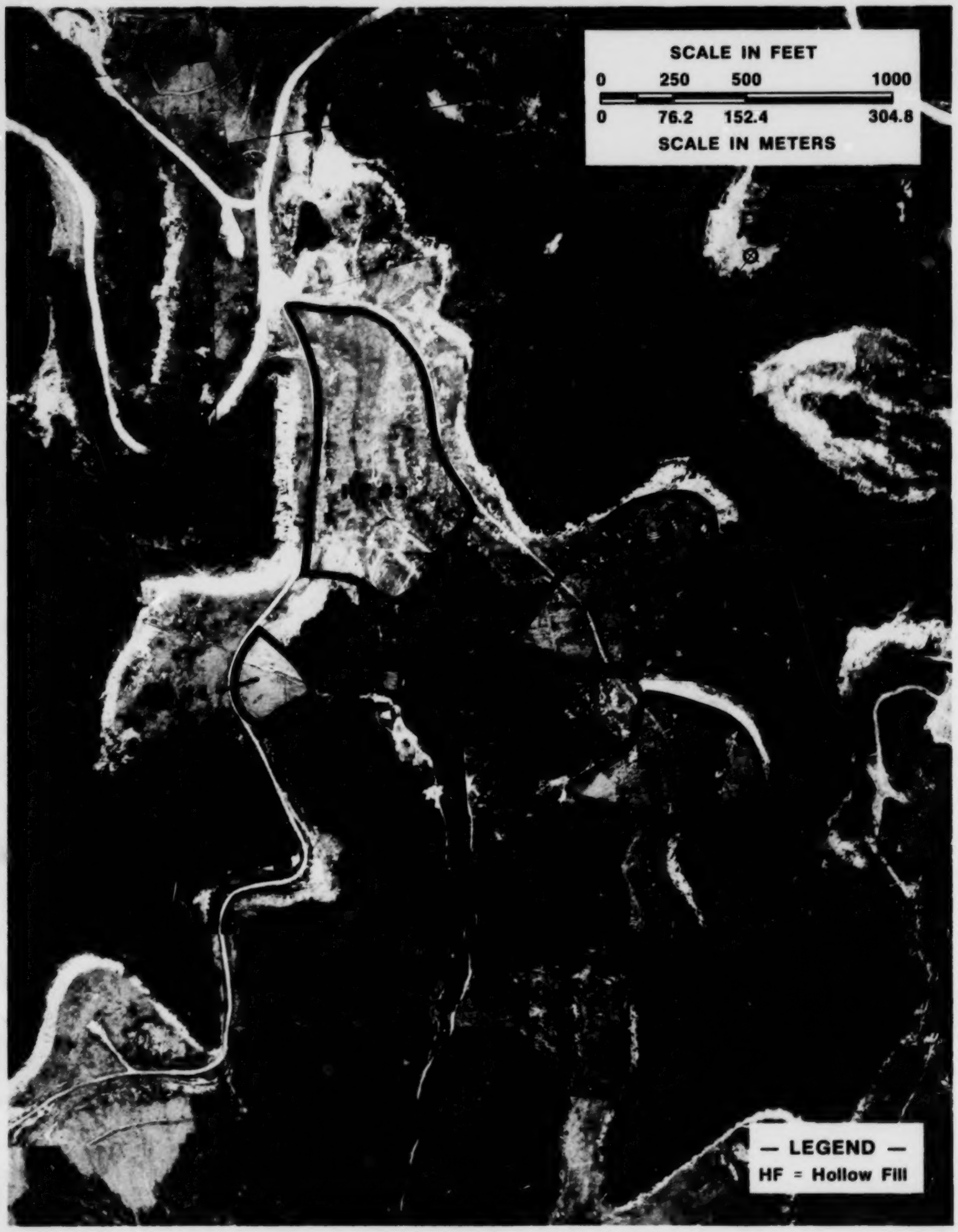

SCALE IN FEET
0
250
500
1000
0
76.2
152.4
304.8
SCALE IN METERS
HF #3
HF #2
HF #4
HF #1
— LEGEND —
HF = Hollow Fill

Figure 6. Intensive site KY-07-LA aerial photo - July 1978.



SCALE IN FEET
0
250
500
1000
0
76.2
152.4
304.8
SCALE IN METERS
— LEGEND —
HF = Hollow Fill

Figure 7. Intensive site KY-07-LA aerial photo - Sept. 1979.

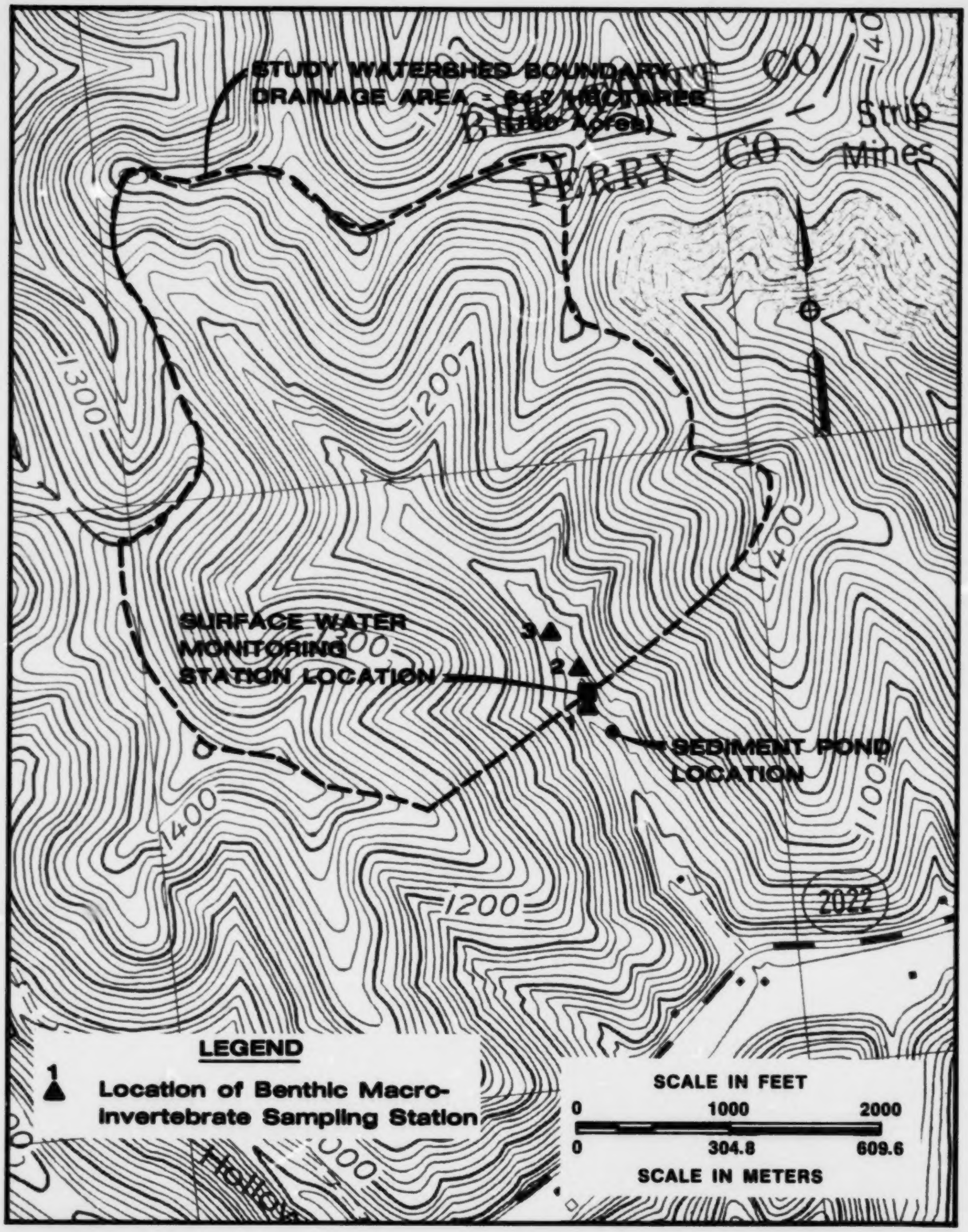

STUDY WATERSHED BOUNDARY
DRAINAGE AREA = 64.7 HECTARES
(160 Acres)
PERRY CO
Strip
Mines
1300
1200
1400
1300
SURFACE WATER
MONITORING
STATION LOCATION
3
2
SEDIMENT POND
LOCATION
1400
1100
1200
2022
LEGEND
1
Location of Benthic Macro-
invertebrate Sampling Station
SCALE IN FEET
0
1000
2000
0
304.8
609.6
SCALE IN METERS
1000
Hollow

Figure 8. Monitoring station locations - intensive site KY-07-LA.

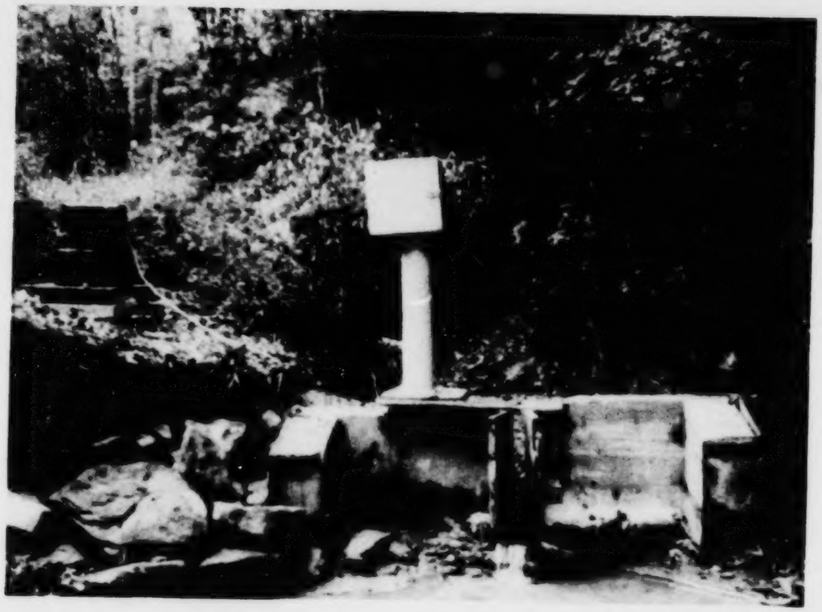


Figure 9. Surface water monitoring station.

During this period, a total of eighteen storm events were monitored for which hydrographs were recorded. Unfortunately, no hydrographs were available during storm events in the period of active mining. Individual hydrographs are presented in Appendix A. Rainfall data for these storms were obtained from the National Weather Service rain gauge located nearest the study watershed. Table 2 lists the rainfall, runoff, and percent of runoff data for each storm event monitored. Monthly rainfall data for the study period are listed in Table 3. Runoff volume was computed by measuring the area underneath each hydrograph taking care not to include base flow. After measuring the total storm runoff volume, this was converted into a runoff volume per unit drainage area (cm) for purposes of data comparison. Figure 11 is a graphical plot of rainfall vs. percent runoff for the monitored storm events. The storm events were grouped into two sets of data points, pre-mining consisting of four storm events and post-mining consisting of fourteen events. The "best fit" straight line was drawn for each group of data based upon the least squares method of linear regression. A correlation coefficient was computed for each group of data. The correlation coefficient is 0.987 for the pre-mine data and 0.811 for the post-mine data. Although the sample

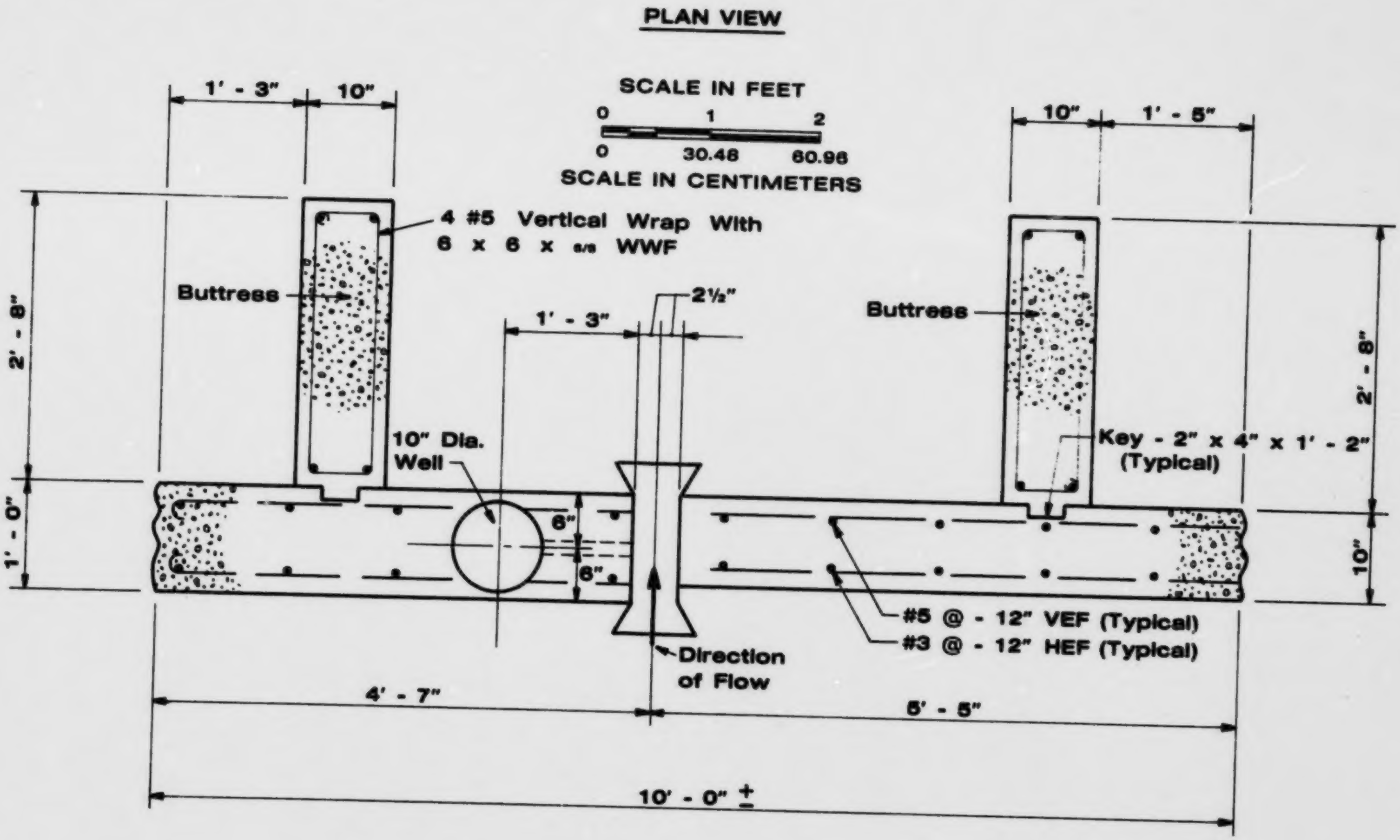

PLAN VIEW
SCALE IN FEET
0
1
2
0
30.48
60.96
SCALE IN CENTIMETERS
1' - 3"
10"
10"
1' - 5"
4 #5 Vertical Wrap With 6 x 6 x 8/8 WWF
Buttress
Buttress
2' - 8"
2' - 8"
2½"
1' - 3"
10" Dia. Well
Key - 2" x 4" x 1' - 2" (Typical)
1' - 0"
10"
6"
6"
#5 @ - 12" VEF (Typical)
#3 @ - 12" HEF (Typical)
Direction of Flow
4' - 7"
5' - 5"
10' - 0" ±

Figure 10. Construction drawing - surface water monitoring station.

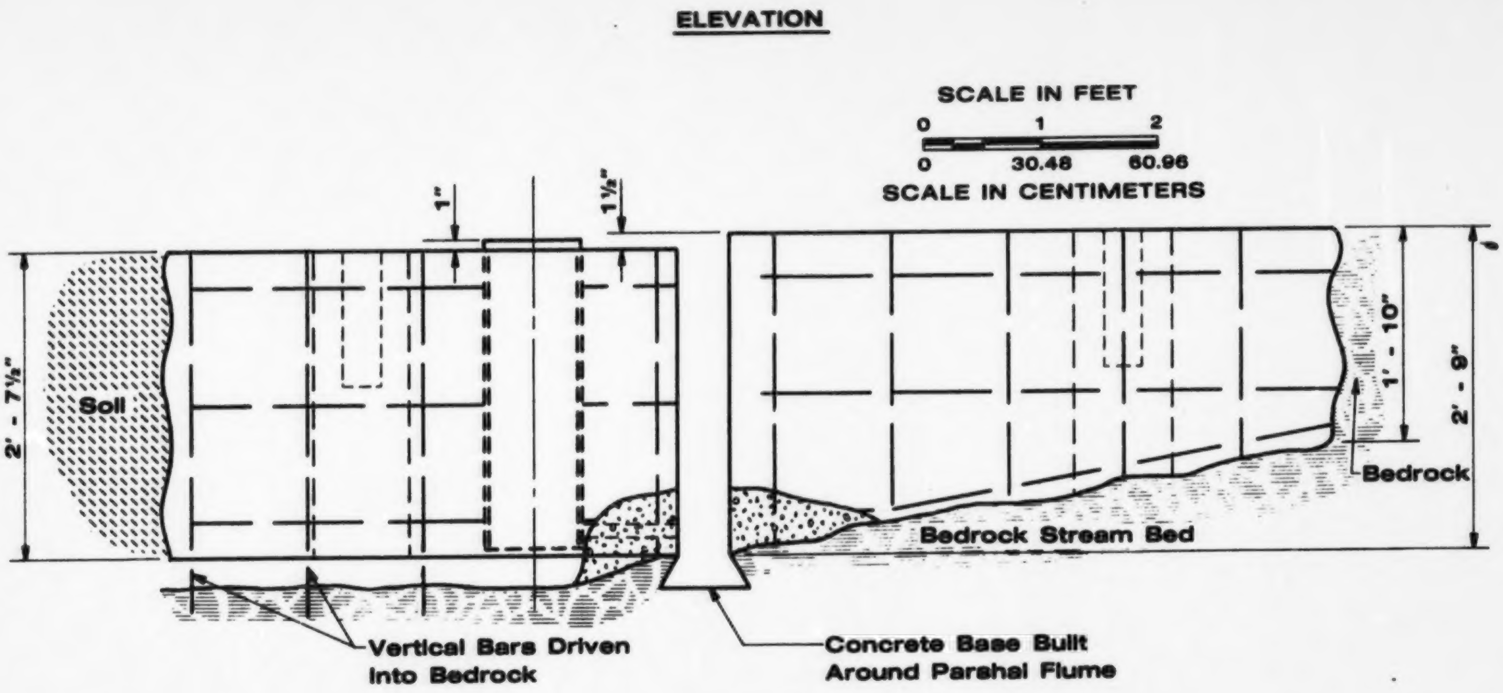

ELEVATION
SCALE IN FEET
0
1
2
0
30.48
60.96
SCALE IN CENTIMETERS
1"
1½"
2' - 7½"
Soil
1' - 10"
2' - 9"
Bedrock
Bedrock Stream Bed
Vertical Bars Driven Into Bedrock
Concrete Base Built Around Parshal Flume

Figure 10. (continued)

TABLE 2. RAINFALL/RUNOFF FOR KENTUCKY STUDY WATERSHED

Date Pre-mining	Rainfall cm	Rainfall in	Runoff cm	Runoff in	% Runoff
5/30/76	1.40	0.55	0.023	0.009	1.64
5/30-6/4/76	5.72	2.25	1.575	0.620	27.6
8/15/76	1.78	0.70	0.010	0.004	0.57
9/27/76	2.03	0.80	0.018	0.007	0.88
Post-mining					
3/3-4/77	1.65	0.65	0.018	0.007	1.08
3/22/77	1.27	0.50	0.076	0.030	6.00
12/15/77	0.51	0.20	0.002	0.0007	0.35
4/24-25/78	0.89	0.35	0.010	0.004	1.14
4/25-29/78	4.70	1.85	1.041	0.410	22.2
5/4-5/78	0.76	0.30	0.041	0.016	5.33
5/23-24/78	3.43	1.35	0.254	0.100	7.41
6/25-26/78	0.64	0.25	0.008	0.003	1.20
7/9-10/78	2.92	1.15	0.203	0.080	6.96
7/11-12/78	1.40	0.55	0.051	0.020	3.64
8/4/78	0.38	0.15	0.008	0.003	2.00
8/5/78	0.64	0.25	0.041	0.016	6.40
8/7/78	1.40	0.55	0.102	0.040	7.29
8/31/78	1.52	0.60	0.038	0.015	2.50

sizes are small, some conclusions can be drawn from Figure 11. Prior to mining there was no runoff until 1.5 cm (0.6 inch) of rain had fallen and during the post-mining period runoff began almost immediately. Also, the rate of runoff increased faster during the pre-mining period than the post-mining period.

TABLE 3. MONTHLY RAINFALL MEASURED AT BUCKHORN LAKE, KY. 1976-78

Month	1976		1977		1978	
	(cm)	(in)	(cm)	(in)	(cm)	(in)
January			6.4	1.5	14.0	5.5
February			3.8	0.9	3.0	1.2
March			6.1	2.4	10.4	4.1
April			14.7	5.8	9.4	3.7
May	7.6	3.0	3.0	1.2	12.7	5.0
June	13.5	5.3	13.7	5.4	6.6	2.6
July	13.5	5.3	6.4	2.5	9.9	3.9
August	6.1	2.4	16.0	6.3	12.4	4.9
September	8.9	3.5	5.1	2.0	0.5	0.2
October	13.0	5.1	11.9	4.7		
November	2.8	1.1	11.4	4.5		
December	7.4	2.9	6.1	2.4		

SOURCE: National Oceanic and Atmospheric Administration

Another evaluation performed on the rainfall runoff data was the determination of the rainfall response or R-index for storms greater than 2.54 cm (1 inch). The R-index is computed as follows:

$$\frac{\Sigma\ (Q/P)}{n}$$

where Q = stormflow in centimeters over drainage basin
P = storm rainfall in centimeters
n = number of storms
R = R-index

A total of four monitored storms occurring during the study period were analyzed for the R-index and are listed in Table 4.

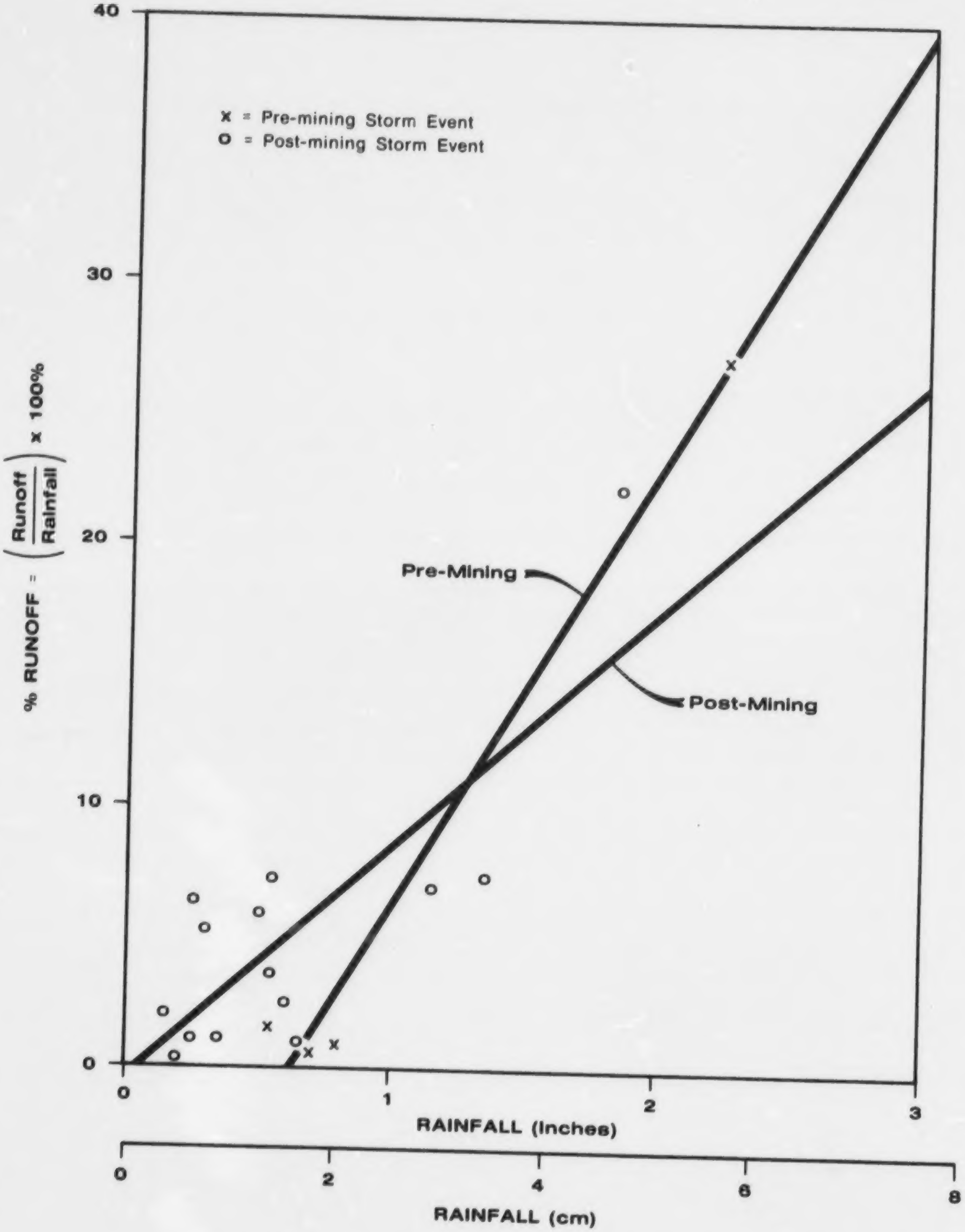


Figure 11. Rainfall vs. percent runoff for intensive site KY-07-LA.

TABLE 4. R-INDEX - KENTUCKY STUDY WATERSHED

Date	P Rainfall (cm)	Q Runoff (cm)	Q/P R-Index
5/30-6/4/76	5.71	1.575	0.27
4/26-29/78	4.70	1.041	0.22
5/23-24/78	3.42	0.254	0.07
7/9-10/78	2.92	0.203	0.07

$$\frac{\Sigma\ (Q/P)}{n}$$

$$\frac{0.63}{4}$$

The calculated R-index (0.16) is less than the R-index (0.46) presented for eastern Kentucky by Bryan and Hewlitt (1979). The variation between these values may be explained by the small sample size (4 events) in this study and its much smaller drainage area (0.64 km ^{2}, 0.25 miles^2) relative to that of Bryan and Hewlitt (156.9-523.2 km ^{2}, 60.6-202 miles^2).

Water Quality

Water quality monitoring for the study watershed began in May 1976 after installation of the surface water monitoring station. An ISCO model 1680 automatic water sampler was installed at the previously described station in conjunction with the Parshall flume and Stevens Total Flow Meter. The ISCO Water Sampler contains 28 sample bottles and can be set for composite or discrete sampling based upon time or flow volume. For this installation, the water sampler was set to sample every six hours and to composite four samples into one container. The end result was a daily composite sample. These daily samples were collected by a field technician. Seven daily samples were composited based upon flow measurements to constitute a weekly composite sample. The weekly composite samples were transported to the laboratory for analysis. In the laboratory, a further composite of the weekly samples was made to produce a composite sample based upon a calendar month.

Fourteen weekly composite water quality samples were collected upstream (influent) of the planned location of the sedimentation pond prior to initiation of mining. Eighteen such samples were collected at this location after mining began and sixty-seven were collected after mining had ceased. Each sample was analyzed for the following parameters using the methods noted:

Parameter	Method
pH	*APHA 221
Total Alkalinity	APHA 201
Hot Acidity	APHA 201
Turbidity	APHA 232
Total Solids	APHA 224
Total Iron	**EPA
Sulfate	APHA 156

*Standard Methods for the Examination of Water and Wastewater. 1975. 14th edition. APHA-AWWA-WPCF.

**Manual of Methods for Chemical Analysis of Water and Wastes. 1974. EPA-625/6-74-003. U.S. Environmental Protection Agency, Washington, D.C.

Means, standard deviations, and ranges measured for these parameters are shown in Table 5. Individual sample data are presented in Appendix B. Figure 12 indicates the relative changes in water quality during the study period.

After the sedimentation pond was constructed, ten and sixty-six weekly grab water quality samples were collected from the effluent during active mining and post-mining, respectively. Each sample was analyzed for turbidity and suspended solids. Means, standard deviations, and ranges measured for these parameters are shown in Table 6. Individual sample data are presented in Appendix B.

Subsamples of the above weekly samples collected at both locations were composited on a calendar month basis. Each monthly composite was analyzed for all the above parameters plus the following: Conductivity, calcium, magnesium, manganese, dissolved iron, aluminum, copper, zinc, cadmium, and nickel. Specific conductivity was determined following Standard Methods (APHA 226) and the metals were determined by atomic absorption spectrophotometer methods specified by EPA. Means, standard deviations, and ranges measured for these parameters are shown in Tables 7 and 8. Individual sample data are presented in Appendix B.

Weekly composite data (Table 5) indicate a change in quality of water leaving the mine site after start of mining. The data show a slight drop in the pH range with an increase in hot acidity (1.0 to 6.8 mg/l). Turbidity (10.4 to 109.7 JTU), total solids (62.8 to 231.4 mg/l), total iron (0.1 to 1.3 mg/l), and sulfate (9.3 to 23.4 mg/l) all substantially increased.

Cessation of mining manifested itself in water quality changes in two ways (Table 5). Hot acidity (6.8 to -102.0 mg/l) decreased with a simultaneous increase in total alkalinity (30.2 to 114.9 mg/l), resulting in a rise in pH values. Total iron (1.3 to 8.9 mg/l), turbidity (109.7 to 279.8 JTU), total solids (231.4 to 2208.8 mg/l), and sulfate (23.4 to

TABLE 5. WATER QUALITY DATA (MEANS, STANDARD DEVIATIONS AND RANGES) OF WEEKLY COMPOSITE SAMPLES COLLECTED UPSTREAM OF THE SEDIMENTATION POND AT INTENSIVE SITE KY-07-LA DURING THE PRE-MINING, ACTIVE MINING AND POST-MINING PERIODS

Period	Number of samples	Statistic	pH	Total alkalinity (mg/l $CaCO_3$)	Hot acidity (mg/l $CaCO_3$)	Turbidity (JTU)	Total solids (mg/l)	Total iron (mg/l)	Sulfate (mg/l)
Pre-mining	14	Mean		17.1	1.0	10.4	62.8	0.1	9.3
		Std. Dev.		3.8	1.9	7.5	27.6	0.1	3.0
		Range	5.7-7.1	10-22	0.6	<5-30	31-116	0.0-0.2	4.1-16.0
Active mining	18	Mean		30.2	6.8	109.7	231.4	1.3	23.4
		Std. Dev.		16.0	17.6	242.2	197.0	2.2	19.6
		Range	5.3-6.9	8-50	-20-42	<5-920	25-700	0.01-8.10	10.0-19.0
Post-mining	67	Mean		114.9	-102.0	279.8	2208.8	8.9	208.1
		Std. Dev.		29.2	-53.1	321.6	5591.5	23.5	115.5
		Range	6.0-8.3	29-168	-214-36	6-1320	17-31545	0.1-170.0	27.0-500.0

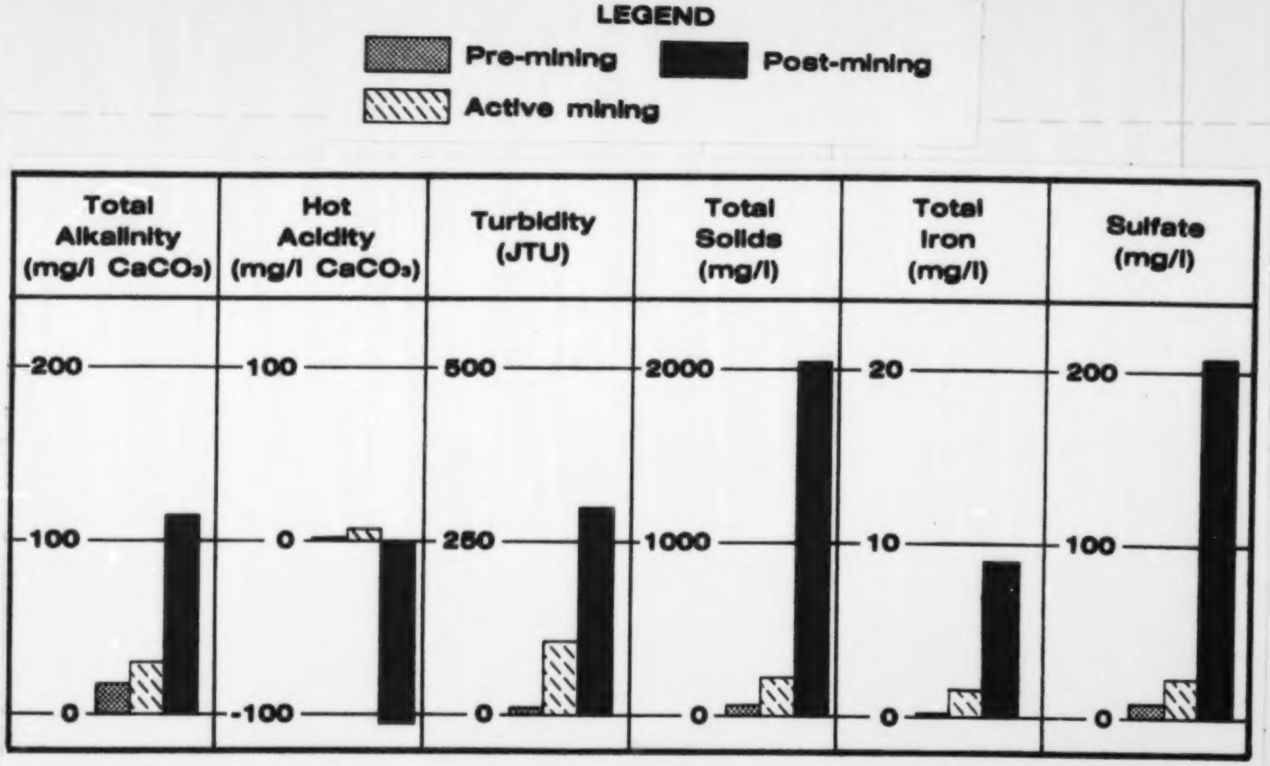


Figure 12. Water quality changes during mining at intensive site KY-07-LA.

TYPING GUIDE SHEET

TABLE 6. WATER QUALITY DATA (MEANS, STANDARD DEVIATIONS AND RANGES) OF WEEKLY GRAB SAMPLES COLLECTED AT THE EFFLUENT OF THE SEDIMENTATION POND AT INTENSIVE SITE KY-07-LA DURING THE ACTIVE MINING AND POST-MINING PERIODS

Period	Number of samples	Statistic	Turbidity (JTU)	Suspended solids (mg/l)
Active mining	10	Mean	35.5	246.5
		Std. Dev.	38.9	675.3
		Range	4-110	6-2168
Post-mining	66	Mean	228.0	399.5
		Std. Dev.	364.8	886.3
		Range	2-1960	3-6852

208.2 mg/l) increased. Thus, the end of mining mitigated the acid nature of the water, but increased its sediment load.

Monthly composite samples (Tables 7 and 8) generally show that the concentrations of other water constituents increased following the end of mining. Only dissolved iron and cadmium remained at the same levels above the sedimentation pond.

Water samples were collected much more frequently above (influent) than below (effluent) the sedimentation pond, every 6 hours versus weekly. However, comparison of values measured above (influent) and below (effluent) the sedimentation pond allow approximation of its efficiency as an instrument of water quality improvement during and after mining (Tables 7 and 8). The sedimentation pond did not appear to be efficient in removal of suspended load during mining because turbidity (influent = 91.5, effluent = 92.0 JTU), suspended solids (72.5, 104.0 mg/l), and total solids (206.5, 190.0 mg/l) decreased slightly or were higher in the effluent than in the influent. However, following cessation of mining the performance of the sedimentation pond improved with respect to removal of suspended solids (3473.9, 718.4 mg/l) and total solids (3810.4, 1162.3 mg/l).

In conclusion, increased acidity and suspended load indicated a deterioration of the quality of water leaving the mine area following initiation of mining. The water was less acid, but carried even more suspended load after mining had ceased. During mining, the sedimentation pond did not appear to reduce the suspended load. Following the end of mining, the pond was much more efficient in removal of suspended solids.

Stream Benthic Macroinvertebrate Community

Samples of the benthic macroinvertebrate community present in the stream receiving runoff from Intensive Site KY-07-LA were collected during

TABLE 7. WATER QUALITY DATA (MEANS, STANDARD DEVIATIONS AND RANGES) OF MONTHLY COMPOSITE SAMPLES COLLECTED AT THE INFLUENT OF THE SEDIMENTATION POND AT INTENSIVE SITE KY-07-LA DURING THE ACTIVE MINING AND POST-MINING PERIODS

Parameter	Active mining			Post-mining		
	Mean	Std. Dev.	Range	Mean	Std. Dev.	Range
pH			6.5-7.4			6.4-6.9
Total alkalinity (mg/l $CaCO_3$)	50.0	5.7	46-54	102.4	33.5	42-150
Hot acidity (mg/l $CaCO_3$)	-19.0	4.2	-22-(-16)	-83.1	42.8	-142-(-16)
Turbidity (JTU)	91.5	2.1	90-93	411.1	431.9	40->1000
Total solids (mg/l)	206.5	23.3	190-223	3810.4	5480.4	397-17200
Suspended solids (mg/l)	72.5	3.5	70-75	3473.9	5600.6	175-17200
Conductivity (µmhos/cm)	200.0	56.6	160-240	490.0	220.8	180-710
Sulfate (mg/l)	30.0	0.0	same	170.0	106.0	50-360
Calcium (mg/l)	15.0	0.0	same	54.9	26.1	18-106
Magnesium (mg/l)	13.0	4.2	10-16	32.8	16.8	9-64
Manganese (mg/l)	0.6	0.3	0.4-0.8	2.0	2.2	0.6-7.7

(continued)

TABLE 7. (continued)

Parameter	Active mining			Post-mining		
	Mean	Std. Dev.	Range	Mean	Std. Dev.	Range
Total iron (mg/l)	0.5	0.2	0.3-0.6	18.9	36.6	2.4-116.0
Dissolved iron (mg/l)	0.1	0.0	same	0.1	0.2	0.0-0.4
Aluminum (mg/l)	0.2	0.0	same	10.8	17.3	0.7-56.0
Copper (mg/l)	<0.01	0.0	same	0.04	0.05	<0.01-0.17
Zinc (mg/l)	0.03	0.0	same	0.15	0.14	0.03-0.44
Cadmium (mg/l)	<0.01	0.0	same	<0.01	0.00	same
Nickel (mg/l)	<0.03	0.0	same	0.06	0.06	<0.03-0.20

Number of samples: Active mining - 2
Post-mining - 9

TABLE 8. WATER QUALITY DATA (MEANS, STANDARD DEVIATIONS AND RANGES) OF MONTHLY COMPOSITE SAMPLES COLLECTED AT THE EFFLUENT OF THE SEDIMENTATION POND AT INTENSIVE SITE KY-07-LA DURING THE ACTIVE MINING AND POST MINING PERIODS

	Active mining			Post-mining		
Parameter	Mean	Std. Dev.	Range	Mean	Std. Dev.	Range
pH			6.6-7.2			7.5-8.1
Total alkalinity (mg/l $CaCO_3$)	31.0	1.4	30-32	108.9	17.9	78-156
Hot acidity (mg/l $CaCO_3$)	14.5	6.4	10-19	-98.2	28.7	-164-(-54)
Turbidity (JTU)	92.0	96.2	24-160	414.6	372.7	80->1000
Total solids (mg/l)	190.0	104.7	116-264	1162.3	866.4	331-3500
Suspended solids (mg/l)	104.0	87.7	42-166	718.4	841.4	60-3060
Conductivity (µmhos/cm)	122.5	3.5	120-125	560.7	215.0	285-920
Sulfate (mg/l	25.0	7.1	20-30	216.1	122.1	65-430
Calcium (mg/l)	12.0	8.5	6-18	54.7	19.7	30-93
Magnesium (mg/l)	7.0	0.0	same	34.5	13.8	17-61
Manganese (mg/l)	0.2	0.3	0.0-0.4	1.5	0.6	1.0-2.9

(continued)

TABLE 8. (continued)

Parameter	Active mining Mean	Std. Dev.	Range	Post-mining Mean	Std. Dev.	Range
Total iron (mg/l)	1.0	0.8	0.4-1.6	7.6	6.3	0.8-20.0
Dissolved iron (mg/l)	0.3	0.1	0.2-0.3	0.1	0.1	0.0-0.3
Aluminum (mg/l)	0.6	0.1	0.5-0.6	4.8	3.8	0.4-11.9
Copper (mg/l)	<0.01	0.00	same	0.02	0.01	<0.01-0.04
Zinc (mg/l)	0.03	0.03	0.01-0.05	.41	1.18	<0.01-4.50
Cadmium (mg/l)	<0.01	0.00	same	<0.01	0.00	same
Nickel (mg/l)	<0.03	0.00	same	0.03	0.01	<0.03-0.05

Number of samples: Active mining - 2
Post-mining - 14

the period of active mining, March 16, 1977, and following completion of mining, February 7, 1980. Three sample stations (Figure 8) were established on this stream spanning a distance of 350 m (1150 ft). On each sample date, three replicate samples were collected at each station. Two different types of sampling gear were used, a Surber sampler (net mesh opening = 1.02 mm) March 16, 1977, and a Portable Invertebrate Box Sampler (net mesh opening = 0.21 mm) February 7, 1980.

A detailed physical survey February 7, 1980 indicated that conditions were similar at all stations (Table 9). Ranges were: mean depth 8-10 cm (3-4 in), mean width 46-76 cm (18-30 in), and mean current velocity 0.4-0.6 m/sec (1.4-2.0 ft/sec).

TABLE 9. PHYSICAL SURVEY OF BENTHIC MACROINVERTEBRATE SAMPLE STATIONS ON THE STREAM RECEIVING RUNOFF FROM INTENSIVE SITE KY-07-LA CONDUCTED FEBRUARY 7, 1980.

Parameter	Station 1	Station 2	Station 3
Mean Depth, cm (in)	8 (3)	10 (4)	8 (3)
Mean Width, cm (in)	76 (30)	46 (18)	46 (18)
Mean Current Velocity, m/sec (ft/sec)	0.4 (1.4)	0.6 (2.0)	0.5 (1.7)
Substrate Type	Sand, gravel, and stones to 15 cm (6 in) diameter	Sand, gravel, and stones to 15 cm (6 in) diameter	Sand, gravel, and stones to 15 cm (6 in) diameter
Water Temperature °C(°F)	1°(34°)	1°(34°)	1°(34°)

Each replicate sample was preserved in 70% isopropanol and transported to the laboratory for processing. All macroinvertebrate specimens were sorted from sample residue without flotation, stain, or magnification aid. Using a dissection microscope all specimens were identified to the lowest practicable taxon (family, genus, or species). Mean numerical density per square meter was calculated for each taxon. The standard error of the mean was calculated for each sample collected February 7, 1980. Each standard error was expressed as a percentage of the corresponding sample mean to indicate the amount of error in the sample mean when it was used to estimate the population mean. Only one value (station 1) was below the recommended acceptable standard error (40.0%) in benthic macroinvertebrate sampling (Cummins 1975). However, the practical limitation of restricted substrate surface area prevented collection of additional replicate samples at stations 2 and 3.

In addition to estimating macroinvertebrate numerical densities, all specimens collected February 7, 1980 were weighed to provide total biomass density estimates. The specimens were dried in an oven at 100°C (212°F) for 24 hours, allowed to cool to room temperature in a dessicator, and weighed with a Mettler balance, model #54AR.

Macroinvertebrate species composition (Tables 10 and 11) varied among stations (spatially) and dates (temporally). More total taxa (all stations combined) were collected March 16, 1977 (31) than were collected February 7, 1980 (13). The number of taxa collected at individual stations was the same or increased in an upstream direction both dates.

Total numerical density (all taxa and all stations combined, individuals/m^2) was lower March 16, 1977 (400.2) than February 7, 1980 (5007.6). Total numerical density (all taxa combined) at individual stations was lowest at station 1 both dates and greatest at stations 2 and 3 on alternate dates. Numerically dominant taxa and densities recorded (individuals/m^2) were Chloroperla sp. (63.4), Heptagenia sp. (51.5), Paraleptophlebia sp. (33.5), and Stenonema sp. (32.3) March 16, 1977 and Chironomidae (4935.6) and Ceratopogonidae (25.5) February 7, 1980.

Mean macroinvertebrate biomass (g/m^2) measured February 7, 1980 was higher at station 3 (1.29110) than at stations 1 (0.38037) or 2 (0.08993). This was due to the collection of more specimens of Tipula sp., a species marked by relatively large physical size, at station 3 than at the other stations.

It is difficult to determine whether cessation of surface mining activity in the watershed had a significant impact on this stream's macroinvertebrate communities. The number of taxa collected during the period of active mining (31) was higher than the number collected after mining had ceased (13). However, both collections included mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera), groups traditionally considered pollution sensitive. Numerical population densities were substantially higher after cessation of mining, perhaps due to the replacement of the Surber sampler (SS) with the Portable Invertebrate Box Sampler (PIBS) as the sampling device. The smaller net mesh opening (0.21 mm) of the PIBS relative to that of the SS (1.02 mm) would allow the PIBS to retain smaller individuals that would have passed through the SS.

Terrestrial Vegetation

Several surveys were conducted at the Kentucky mine site to describe the herbaceous and woody components of the terrestrial vegetation prior to disruption by mining. Herbaceous vegetation (wildflowers and shrubs) was studied in June 1977 and May 1978. Woody vegetation (trees) was studied in March 1977.

On the herbaceous vegetation study dates, specimens were collected, preserved, and transported to the laboratory for identification. Taxonomy is that of Strausbaugh and Core (1970, 1971, 1973, 1977), a

TABLE 10. BENTHIC MACROINVERTEBRATE DATA FROM SAMPLES COLLECTED IN THE STREAM RECEIVING RUNOFF FROM INTENSIVE SITE KY-07-LA MARCH 16, 1977

	Mean numerical density (No/m^2)			
Taxon	Station 1	Station 2	Station 3	All Stations
Decapoda				
Astacidae	3.6		7.2	3.6
Plecoptera				
Acroneuria sp.			39.5	13.2
Chloroperla sp.		32.3	158.0	63.4
Leuctra sp.		3.6	3.6	2.4
Perlodidae		7.2	10.8	6.0
Ephemeroptera				
Ameletus sp.	18.0	10.8	14.4	14.4
Baetis sp.		3.6	43.1	15.6
Ephemerella sp.		7.2	7.2	4.8
Heptagenia sp.	10.8	75.4	68.2	51.5
Heptageniidae		10.8	39.5	16.8
Paraleptophlebia sp.	35.9	28.7	35.9	33.5
Stenonema sp.		3.6	93.3	32.3
Odonata				
Cordulegaster sp.		3.6		1.2
Libellulidae		3.6		1.2
Megaloptera				
Nigronia sp.			3.6	1.2
Trichoptera				
Cheumatopsyche sp.		7.2	7.2	4.8
Glossosoma sp.	18.0	18.0	18.0	18.0
Lepidostoma sp.	3.6	7.2		3.6
Psychomyiidae		3.6	7.2	4.8
Pycnopsyche sp.	3.6	7.2	3.6	4.8
Trentonius sp.		3.6		1.2

(continued)

TABLE 10. (continued)

Taxon	Station 1	Mean numerical density (No/m^2) Station 2	Station 3	All Stations
Coleoptera				
Ectopria sp.		14.4	53.9	22.8
Macronychus sp.	7.2	28.7	35.9	23.9
Psephenus sp.		10.8	53.9	21.6
Diptera				
Bezzia sp.			3.6	1.2
Chironomidae	39.5	10.8		16.8
Eriocera sp.		18.0		6.0
Procladius sp.	7.2		7.2	4.8
Stratiomyiidae			3.6	1.2
Tipula sp.			3.6	1.2
Tipulidae		3.6	3.6	2.4
All Taxa	147.4	323.5	725.6	400.2
Total Taxa Collected	10	25	25	31

TABLE 11. BENTHIC MACROINVERTEBRATE DATA FROM SAMPLES COLLECTED IN THE STREAM RECEIVING RUNOFF FROM INTENSIVE SITE KY-07-LA FEBRUARY 7, 1980

Taxon	Mean Numerical Density (Nc/m^2) Station 1	Station 2	Station 3	All Stations
Decapoda				
Astacidae	3.3			1.1
Plecoptera				
Brachyptera sp.	13.3	6.7		6.7
Leuctra sp.		3.3	3.3	2.2
Nemoura sp.		13.0	3.3	5.4
Ephemeroptera				
Ephemerella sp.			3.3	1.1
Trichoptera				
Diplectrona sp.	3.3	10.0	13.3	8.9
Polycentropus sp.			3.3	1.1
Megaloptera				
Sialis sp.			3.3	1.1
Diptera				
Ceratopogonidae	3.3	13.3	60.0	25.5
Chironomidae	1826.7	9236.7	3743.4	4935.6
Empididae			20.0	6.7
Tipula sp.	6.7		20.0	8.9
Tipulidae		3.3	6.7	3.3
All Taxa	1856.6	9286.3	3879.9	5007.6
Standard Error (SE)	312.2	7476.4	2447.2	--
SE as % of Total Number	16.8	80.5	63.1	--
Total Taxa Collected	6	7	11	13
Mean Biomass (g/m^2)	0.38037	0.08993	1.29110	0.58713

series of keys to the vegetation of West Virginia considered applicable because of the short distance separating eastern Kentucky and West Virginia.

The technique employed in study of the woody vegetation is called the random-pairs sampling method as outlined in Mueller-Dumbois and Ellenberg (1974). It is a plotless method used in analysis of terrestrial vegetation. A series of randomly selected points was established on the site. At each point the observer faced the nearest tree and then selected a second tree behind him closest to the initial tree. All selected trees were identified and their diameters measured at breast height. The distance between the trees in each pair was measured.

Twenty-six herbaceous species were collected both sample dates, including ferns and wildflowers (Table 12). With exception of three species, Sedum ternatum (Wild Stonecrop), Senecio aureus (Golden Ragwort), and Verbascum thapsus (Great Mullein) not collected June 1977, all were collected both sample dates. Although most species were unrelated gener-

TABLE 12. HERBACEOUS SPECIES COLLECTED AT INTENSIVE SITE KY-07-LA JUNE, 1977 AND MAY, 1978

Scientific Name	Common Name
Arisaema triphyllum	Jack-in-the-pulpit
Chimaphila maculata	Spotted Wintergreen
Erigeron philadelphicus	Philadelphia Fleabane
Fragaria vesca	Woodland Strawberry
Geranium maculatum	Wild Geranium
Gerardia virginica	Downy Yellow Foxglove
Goodyera pubescens	Downy Rattlesnake Plantain
Heuchera americana	Alumroot
Houstonia caerulea	Bluets
Iris cristata	Crested Dwarf Iris
Obolaria virginica	Pennywort
Oxalis grandis	Large Yellow Wood Sorrel
Phlox divaricata	Wild Blue Phlox
Polystichum acrostichoides	Christmas Fern
Potentilla simplex	Common Cinquefoil
Ranunculus hispidus	Hispid Buttercup
*Sedum ternatum	Wild Stonecrop
*Senecio aureus	Golden Ragwort
Taraxacum officinale	Common Dandelion
Trillium grandiflorum	Large Flowered Trillium
*Verbascum thapsus	Great Mullein
Vicia caroliniana	Wild Vetch
Viola papilionacea	Common Blue Violet
V. rostrata	Long-spurred Violet
V. sagittata	Arrow-leaf Violet
V. striata	Striped Violet

* Not collected June 1977.

ically, four species of violets, *Viola papilionacea* (Common Blue Violet), *V. rostrata* (Long-spurred Violet), *V. sagittata* (Arrow-leaf Violet), and *V. striata* (Striped Violet), were collected.

Fifteen species were identified in a sample of 108 trees numerically dominated by 38 White Oaks (*Quercus alba*) and 18 Black Oaks (*Q. velutina*) (Table 13). The Black Oaks were bigger trees because their total basal area or trunk cross-sectional area was nearly equal, 14071.6 cm^2 (2181.1 in^2) to that of the White Oaks, 15533.5 cm^2 (2407.7 in^2) (Table 14). The total basal area of all trees observed was 51320.7 cm^2 (7956.8 in^2). The trees were relatively close together, mean distance measured between individuals 5.0 m (16.4 ft). With the mean canopy area of an individual tree 24.7 m^2 (269.0 ft^2), the density of trees was 65.4 trees/hectare (162.0 trees/acre). Importance value, a numerical quantity calculated for each species incorporating the number of individuals, the total basal area, and the relative frequency of occurrence, was greatest for White Oaks (94.21%) and Black Oaks (67.15%).

Data for individual pairs of trees are presented in Appendix C.

TABLE 13. TREE SPECIES IDENTIFIED AND TOTAL NUMBER COUNTED IN SAMPLE PLOTS AT INTENSIVE SITE KY-07-LA MARCH, 1977

Scientific Name	Common Names	Number of Trees
Acer rubrum	Red Maple	5
A. saccharum	Sugar Maple	5
Betula lenta	Black Birch	2
Carya ovata	Shagbark Hickory	6
Cornus florida	Flowering Dogwood	4
Fagus grandifolia	American Beech	8
Juglans nigra	Black Walnut	1
Liriodendron tulipifera	Yellow-poplar	8
Pinus pungens	Table Mountain Pine	2
Platanus accidentalis	Sycamore	2
Pyrus sp.	Chokecherry	1
Quercus alba	White Oak	38
Q. prinus	Chestnut Oak	6
Q. velutina	Black Oak	18
Sassafras albidum	Sassafras	2
	Total	108

TABLE 14. SUMMARY OF TREE SPECIES DATA COLLECTED THROUGH RANDOM PAIRS SAMPLING AT INTENSIVE SITE KY-07-LA

	Relative density %	Relative dominance %	Frequency	Relative frequency %	Dominance	Importance value %	Basal area (cm^2)	Basal area (in^2)	Density Trees/ hectare	Density Trees acre
American Beech	7.41	20.06	0.13	8.50	1,596.1	35.97	10,300.0	1,596.5	4.8	12.0
Black Birch	1.85	0.36	0.04	2.61	28.6	4.82	183.2	28.4	1.2	3.0
Black Oak	16.67	27.41	0.20	13.07	2,180.9	67.15	14,071.6	2,181.1	10.9	27.0
Black Walnut	0.93	0.73	0.02	1.31	58.1	2.97	374.8	58.1	0.6	1.5
Chestnut Oak	5.56	4.43	0.11	7.19	352.5	17.18	2,272.3	352.2	3.6	9.0
Chokecherry	0.93	0.17	0.02	1.31	13.5	2.41	85.2	13.2	0.6	1.5
Flowering Dogwood	3.70	1.35	0.07	4.58	107.4	9.63	692.9	107.4	2.4	6.0
Red Maple	4.63	1.70	0.09	5.88	135.3	12.21	872.3	135.2	3.0	7.5
Sassafras	1.85	0.49	0.04	2.61	39.0	4.95	253.5	39.3	1.2	3.0
Shagbark Hickory	5.56	2.93	0.11	7.19	233.1	15.68	1,504.5	233.2	3.6	9.0
Sugar Maple	4.63	2.59	0.07	4.58	206.1	11.80	1,329.0	206.0	3.0	7.5
Sycamore	1.85	0.51	0.04	2.61	40.6	4.97	260.6	40.4	1.2	3.0
Table Mountain Pine	1.85	1.02	0.04	2.61	81.2	5.48	523.2	81.1	1.2	3.0
White Oak	35.19	30.26	0.44	28.76	2,407.8	94.21	15,533.5	2,407.7	23.0	57.0
Yellow-Poplar	7.41	5.99	0.11	7.19	476.6	20.59	3,077.4	477.0	4.8	12.0

Mean distance tree to tree: 5.0 m (16.4 ft.)

Total density: 65.4 trees/hectare (162.0 trees/acre)

Mean canopy area: 24.7 m^2 (269.0 ft^2)

Total basal area: 51,320.7 cm^2 (7,956.8 in^2)

SECTION 5
SOUTHERN WEST VIRGINIA MINE SITE

PHYSICAL DESCRIPTION OF THE WEST VIRGINIA STUDY REGION

The physical description of the West Virginia study region was derived from Horn (1960), Kuchler (1964), Clay (1975), Conant (1975), Burt (1975) and Petersen (1947).

Topography

Most of West Virginia can be divided into two major geographic sections. Except for the eastern panhandle which lies in the Ridge and Valley Province, the state lies in the Appalachian Plateau. Because the Allegheny Mountain Chain is the most pronounced feature of the eastern part of the plateau, it is appropriate to consider this section individually.

The Allegheny Mountain Chain contains the highest land in the state. Peak elevations range from about 762 meters (2,500 feet) to 1,481 meters (4,860 feet) above sea level at Spruce Knob. Two topographic characteristics justify recognition of this area as a separate unit. First, the altitudes and the degree of dissection are greater here than in the plateau to the west. Secondly, the rocks of this section are mildly folded, and erosion on anticlines and synclines has produced a number of structurally controlled ridges and valleys that give the topography a pronounced lineation.

The Appalachian Plateau covers the western two-thirds of the state and includes the study region for this project site. Along this division the Allegheny Front segregates the waters destined to the Atlantic Ocean and those flowing to the Gulf of Mexico. The central and western thirds of the plateau generally slope westward to the Ohio River, which lies about 168 to 198 meters (550 to 650 feet) above sea level. It is a region severely dissected by dendritic water courses into a maze-like network of steep hills and narrow valleys. In places, the original plateau surface shows as the uniform top levels of the remaining ridges, although this characteristic is more prevalent in the south where the erosion has been somewhat less than that found in the northern sections. Altitudes are lowest on the western side of the plateau, where they range from 366 to 427 meters (1,200 to 1,400 feet), and increase eastward as they approach the Allegheny Front. The highest point is at its eastern margin in West Virginia where peaks may rise above 1,219 meters (4,000 feet). Cut 610 meters (2,000 feet) below the plateau surface level, the New River gorge is a well known landmark in the eastern United States.

Climatology

The variety of climatic conditions in West Virginia can only be understood in light of the diverse topographic features of the state. Located 241 kilometers (150 miles) from the ocean, West Virginia is characterized by a humid continental climate. The most outstanding aspect of this type of climate is the marked contrast in temperature between summer and winter. The nature of the terrain and general topography, including the fact that the highest elevation on the plateau is along the eastern border, have important climatic effects.

Temperature variations across the state illustrate the effect of the topography. There is about as much temperature change across the state from east to west as there is in twice the distance from north to south. This variation is due to the mountains in the east where lower temperatures may be expected. Average winter minimum temperatures range from -7°C (20°F) in the mountains of the eastern and northern Panhandle, to near -1°C (30°F) in the extreme southern and southwestern portions of the state, where this study has been concentrated. Average winter maximums vary from 7°C to 10°C (45°F to 50°F), except in the mountains where they are several degrees lower. Summer brings temperatures that consistently average over 29°C (85°F) with similar geographic variations. Average minimums in summer range from 13°C (55°F) in the mountains to 18°C (65°F) elsewhere. Spring and autumn mean temperatures range between 10°C and 15°C (50°F to 59°F) and are also lower in the eastern mountains.

The last freezing day in the study area can be expected some time in mid-April. Temperatures of over 38°C (100°F) have been recorded at all stations in the state, up to 44°C (112°F) in one instance. Very low temperatures have been noted to -38°C (-37°F) at Lewisburg. During an average winter, cold waves with -18°C (0°F) or lower temperatures arrive about three times, but usually do not last more than three or four days.

Precipitation characteristics in the state are also largely a result of topographic effects. Yearly total precipitation in the central section of the state is usually in excess of 152 cms (60 inches). West of this section, amounts decrease to about 101 cms (40 inches) near the Ohio River. East of the central sector, precipitation decreases dramatically to about 76 cms (30 inches) with an increase to about 101 cms (40 inches) at the extreme eastern tip of the state. This trend is due to precipitation producing atmospheric currents that generally travel eastward. As they move toward the Appalachian Mountains, they are subject to orographic lifting which causes the release of potential precipitation or intensification of present precipitation, resulting in substantial increases from west to east. Annual snowfall exhibits the same characteristics. Snow usually does not stay on the ground for extended periods, since snowstorms are followed by a thawing period; therefore, there is seldom large scale melting in the spring.

West Virginia experiences only 40 percent possible sunshine in the winter, increasing to about 60 percent in the late summer. Cloudiness is most outstanding over the mountains. The annual number of clear days averages from about 80 in the mountains to about 120 in the west.

Another factor inhibiting direct sunlight hours is the fog often prevalent in the state, especially in the valleys. The circumstances contributing to the distribution of fog in the state are diverse. Radiation type valley fogs occur when a high-pressure area is centered over the state, a common occurrence in late summer and fall. Low clouds and fog in the mountains are usually orographic in nature, caused by moist winds moving upslope. Often, due to this phenomenon, there are great differences in these conditions on opposite sides of a ridge.

Thunderstorms occur from 40 to 50 days of the year and are often accompanied by violent local winds. These storms are more common in June and July and often cause flash flooding in the narrow valleys that cut through the plateau. Precipitation accumulations over a 24 hour period have exceeded 13 centimeters (5 inches) all over the state due to these storms. In the northern part of the state, rainfall in excess of 25 centimeters (10 inches) has been recorded within a 24 hour period. Large area storms are more common during the colder half-year. Storms of this nature produce high winds and heavy rain or snow and, in some cases, lead to flooding of river towns.

Because diverse topographic conditions exist in the study region, diverse climatic conditions exist. When compared to the state as a whole, this region shows less severe temperature patterns, but higher than average precipitation rates, since the region is on the windward side of the Appalachian range.

Geology and Soils

The topographic divisions of the state are defined by its geologic setting. The eastern panhandle, with its narrow, linear ridges and valleys, is composed of Middle and Lower Paleozoic sedimentary formations. The harder formations, principally sandstones, form the ridges, while the less resistant limestone formations form the valleys.

The Allegheny Mountain Chain is located on the eastern edge of the Appalachian Plateau. The mountain chain differs from the less elevated portions of the plateau to the west because the strata located here are more severely folded. The remainder of the plateau, in which the study region is located, is composed of these Late Paleozoic sedimentary formations, containing many coal seams.

Most of the soil types found in West Virginia can be defined as Dystrochepts (Sols Bruns Acides). The soils are warm, moist Inceptisols which exhibit weakly differentiated horizons showing alteration of parent materials. These soils are also low in bases and have no free carbonates in the subsurface horizons.

Local soil types vary considerably depending on slope and parent material. Any analysis of the implications of soil types within the study region must depend on site specific data.

Hydrology

West Virginia is drained by the Ohio and Potomac Rivers. The Ridge and Valley section of the state is included in the Potomac Basin, while the entire Appalachian Plateau drains to the Ohio River. Several tributaries of the Ohio River drain the study region, including the Big Sandy (Tug), Guyandotte, and Kanawha Rivers. Table 15 includes significant hydrologic data for these rivers. Generally, these three tributaries drain in a northwesterly direction with a dendritic pattern.

TABLE 15. HYDROLOGIC DATA - WEST VIRGINIA STUDY REGION

River	Gauging Station	Drainage Area (km^2)	Average Discharge (m^3/s)	Extreme Discharge (m^3/s) High	Extreme Discharge (m^3/s) Low
Big Sandy	Fort Gay	10,880	121	2,530	Unknown
Guyandotte	Branchland	3,175	45	1,260	.1
Kanawha	Charleston	26,985	410	6,120	29
Ohio	Huntington	144,800	Unknown	1,850	91

(Discharge regulated by Dams and Locks)

Land Use

Land use is controlled by topography. Throughout West Virginia, intensive land use is confined to the stream valleys, leaving the steep mountainsides for forests and mining. In the eastern portion of the state, the stream valleys are very narrow, so that most land is forested and ungrazed woodland. In the western part of the state, stream valleys become wider with more land devoted to cropland and pasture.

All the major urban areas in West Virginia are located in stream valleys: Huntington, Parkersburg and Wheeling are located along the Ohio River; Charleston is located on the Kanawha River. Nearly all transportation routes linking urban areas follow stream valleys. The result of this pattern is intensive strip development in these stream valleys, which are highly susceptible to flood damage.

Vegetation and Wildlife

Vegetation in West Virginia is typical of the deciduous forest biome. Oak, hickory, cherry, and maple are the prevalent hardwood species, intermingled with shortleaf, loblolly, Virginia pine and northern balsam fir. Natural understories include a variety of shrubs, forbs and grasses. Farmlands support corn, small grains, cotton, tobacco and pasture.

A large number of animal species are common to the deciduous forest biome. Nuts and fruits provide food for animals such as the gray squirrel and eastern chipmunk. Important mammals include the white-tailed deer, the eastern mole, black bear, gray and red fox, bobcat, raccoon, fox squirrel, New England cottontail, shortail shrew, opposum, southern flying squirrel and whitefooted mouse.

Two particular plant associations within the deciduous forest biome, the oak-hickory and maple-beech-birch associations, define wildlife species peculiar to those plant associations. The maple-beech-birch association is located in the eastern section of the state, while the western section and the study region is dominated by the oak-hickory association.

Mammal populations are low in the oak-hickory portion of the biome. The association also contains a wide variety of birds and wild turkeys, which feed on shrubs, vines and seeds (acorns) found in this association. Common reptiles include copperheads, rough green snakes, rat snakes, coachwhips, and speckled king snakes.

Among the birds in the maple-beech-birch association are the solitary vireo, black throated blue warbler, blackburnian warbler, and rose breasted grosbeak. Typical reptiles in this association include the eastern garter snake, red-bellied snake, milk snake and eastern ringneck snake.

GENERAL SITE DESCRIPTION

The surface mine site in southern West Virginia chosen for more detailed monitoring (WV-07-SA) is located in Logan County. The watershed under study is tributary to the Guyandotte River. Location of the study watershed is shown in Figure 13. Elevations in the watershed range from 243 meters (800 feet) to 664 meters (2180 feet). The average watershed slope is 15% with side slopes as steep as 60%. Prior to mining, the portion of the watershed under study was undisturbed and consisted of dense deciduous forest.

The mine area under study is a small portion of a large mountaintop removal operation. The total mining area encompasses approximately 81 hectares (200 acres) including mineral area and overburden disposal (valley fill). Mountaintop removal mining was used at this site for extraction of the No. 5 Block coal seam at a bench level of approximately 610 meters (2000 feet). Excess overburden was disposed of in a valley fill located in the upper reaches of the study watershed. The valley fill was constructed using the "West Virginia" method of fill construction in which material is hauled from bench level to the toe of the valley fill. Material is placed in 1.22 meter (4 foot) horizontal lifts and graded by dozer. In the center of the fill, a continuous rock "chimney" drain is placed to handle drainage from the fill surface. The surface of the fill

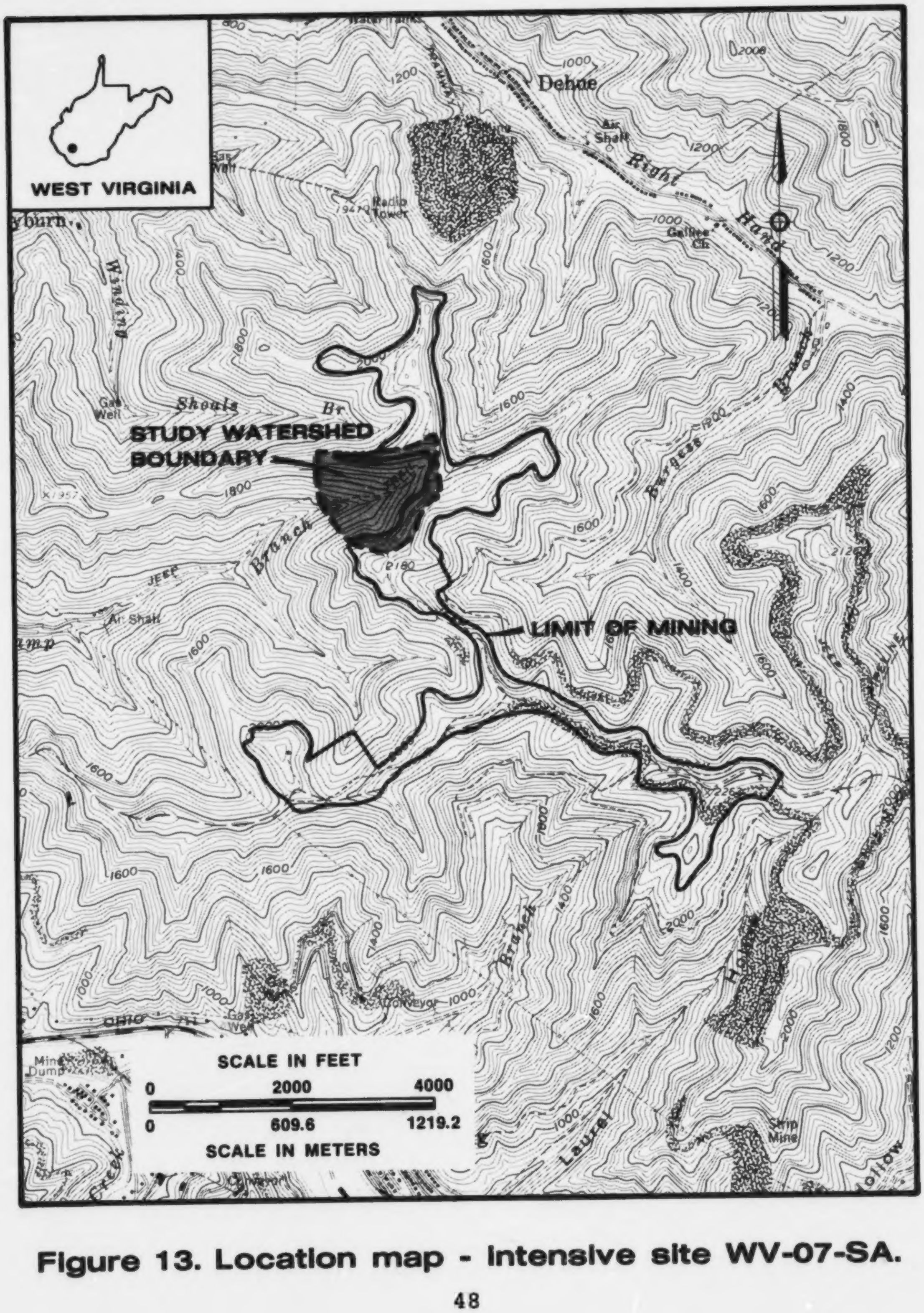

WEST VIRGINIA
Dehue
Air Shaft
Right Hand
Galilee Ch.
Radio Tower
Gas Well
Winding
Shoals Br
STUDY WATERSHED BOUNDARY
Branch
Burgess
LIMIT OF MINING
Air Shaft
Laurel
Strip Mine
Hollow
Mine Dump
Creek
Conveyor
SCALE IN FEET
0
2000
4000
0
609.6
1219.2
SCALE IN METERS

Figure 13. Location map - intensive site WV-07-SA.

is graded to direct drainage to the rock "chimney". Additional 1.22 meter (4 foot) lifts of fill material are added to the surface until a 15.2 meter (50 foot) bench is constructed. As each lift is added, the outslope is graded to a 2:1 slope. After a 15.2 meter (50 foot) bench is completed, the outslope is revegetated. A 6.1 meter (20 foot) terrace is left on the fill surface when the next bench is constructed. An artist's conception of a typical West Virginia valley fill is shown in Figure 14 with cross-sections in Figure 15 detailing important physical characteristics of the fill.

Of the 20 hectares (49 acres) of this watershed, approximately 10 hectares (25 acres) or 50% of the area was to be disturbed by mining. Drainage control for the area was provided by on-bench methods and by a sedimentation pond in the stream's main channel. Mining activities in this watershed began in May 1978 with clearing and grubbing operations. Active mining in the watershed continued throughout the monitoring period which ended in July 1979. To document mine progression, aerial photographs of the mine site were taken on the following dates:

- November 1976;
- July 1978;
- December 1978; and
- September 1979.

The first of the series of photos, Nov. 1976 (Figure 16), shows the watershed in a completely natural state undisturbed by mining. The next photo (July 1978), shows the disturbed mineral area with valley fill #1 nearly completed and the first two 15.2 meter (50 foot) benches of valley fill No. 2 constructed (Figure 17). Photos taken five months later (Dec. 1978), show the mine progression during this time period (Figure 18). Six of the valley fill benches have been completed with construction of the seventh continuing. The outslope of the first three benches has been revegetated for erosion protection. The last of the series of photographs, Sept. 1979 (Figure 19), shows seven of the fill benches completed with work continuing on the eighth. Revegetation of the outslope of the first seven benches has been completed and a good ground cover has been established for erosion protection.

ENVIRONMENTAL MONITORING PROGRAM

The monitoring program for the environmental assessment of this surface mine site consisted of several phases, including:

1. Rainfall/runoff relationship;
2. Water quality;
3. Stream benthic macroinvertebrate community; and
4. Terrestrial vegetation.

Rainfall/Runoff Relationship

Surface water monitoring of this watershed began in September 1976 with the installation of a permanent surface water monitoring station. The station consisted of a 7.6 centimeter (3 inch) Parshall flume

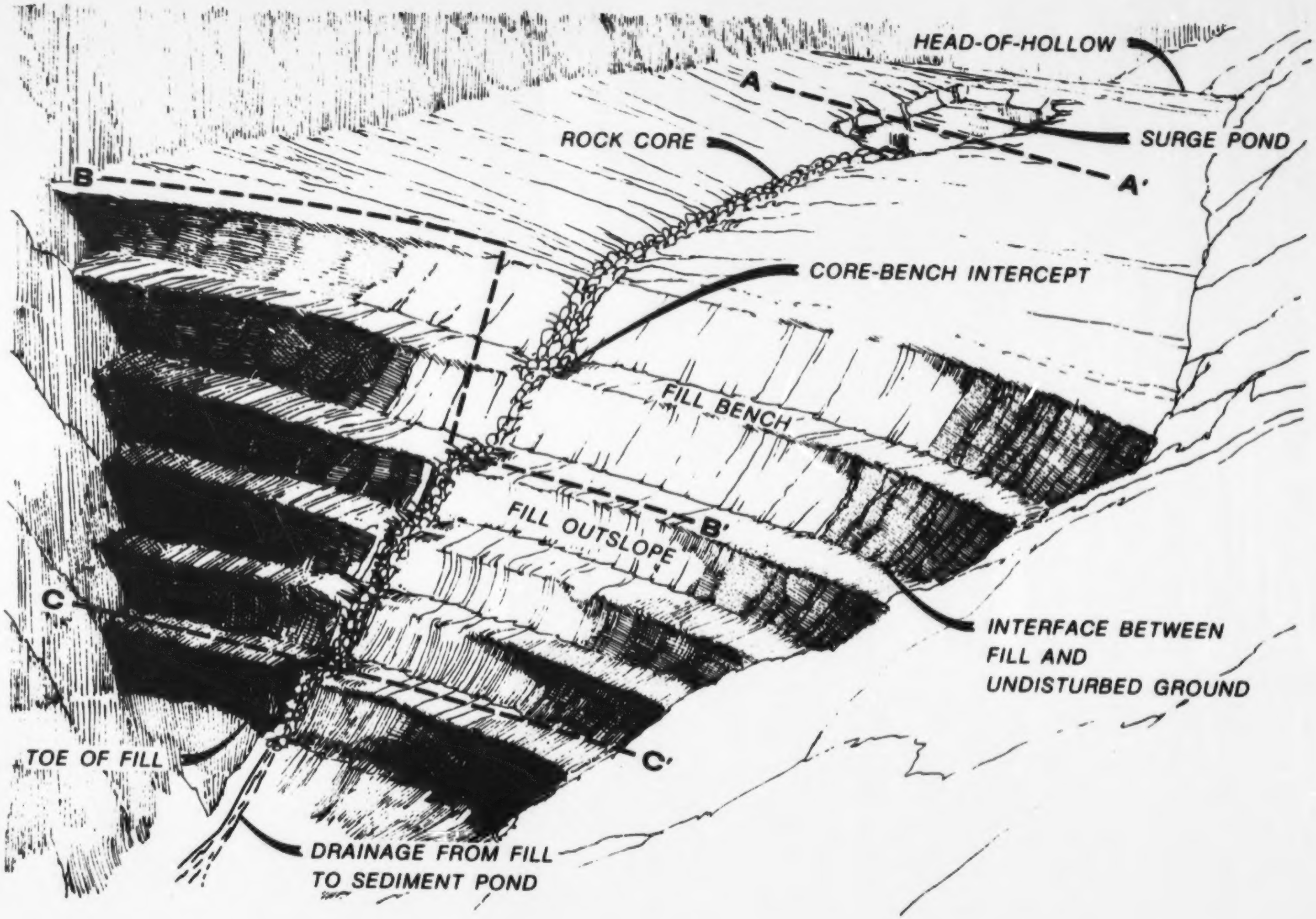
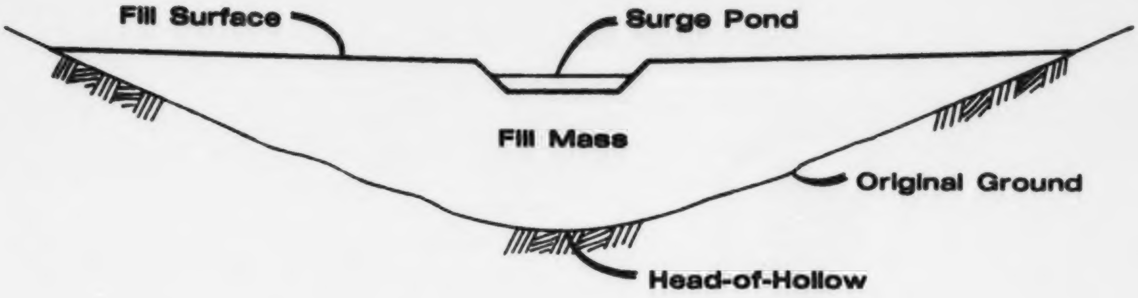
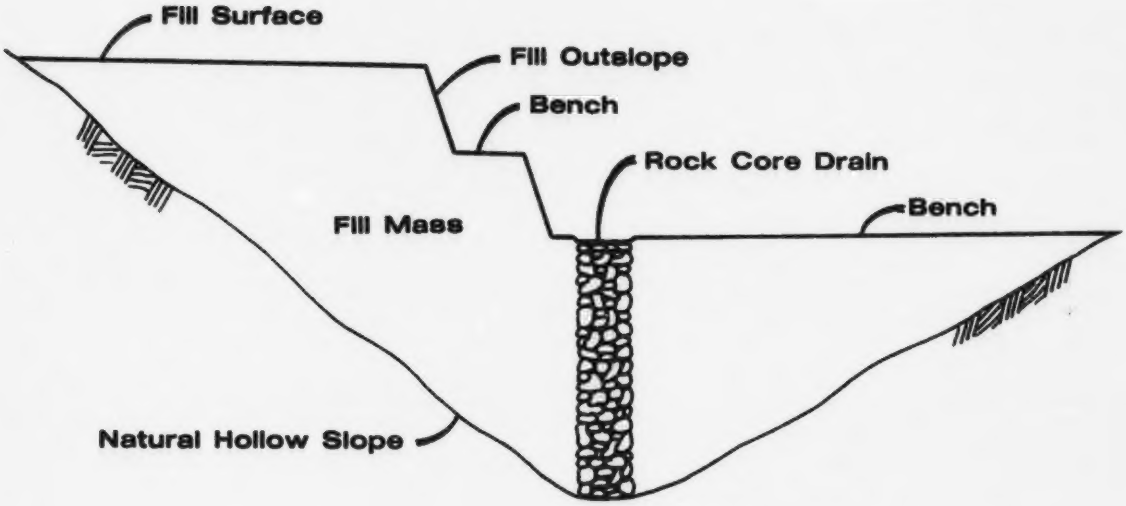

HEAD-OF-HOLLOW
A
SURGE POND
ROCK CORE
A'
B
CORE-BENCH INTERCEPT
FILL BENCH
FILL OUTSLOPE
B'
C
INTERFACE BETWEEN
FILL AND
UNDISTURBED GROUND
TOE OF FILL
C'
DRAINAGE FROM FILL
TO SEDIMENT POND

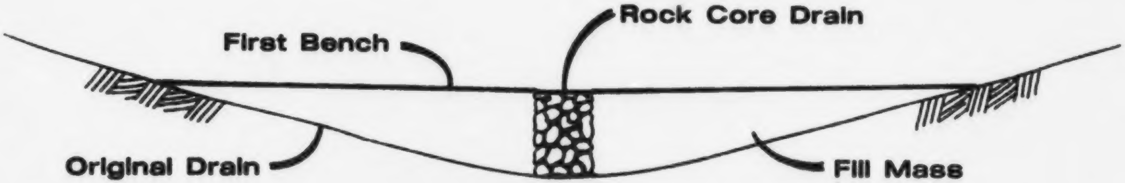
Figure 14. West Virginia head-of-hollow fill.


Fill Surface
Surge Pond
Fill Mass
Original Ground
Head-of-Hollow

SECTION A-A′


Fill Surface
Fill Outslope
Bench
Rock Core Drain
Bench
Fill Mass
Natural Hollow Slope

SECTION B-B′


Rock Core Drain
First Bench
Original Drain
Fill Mass

SECTION C-C′

Figure 15. Cross sections of typical West Virginia head-of-hollow fill.

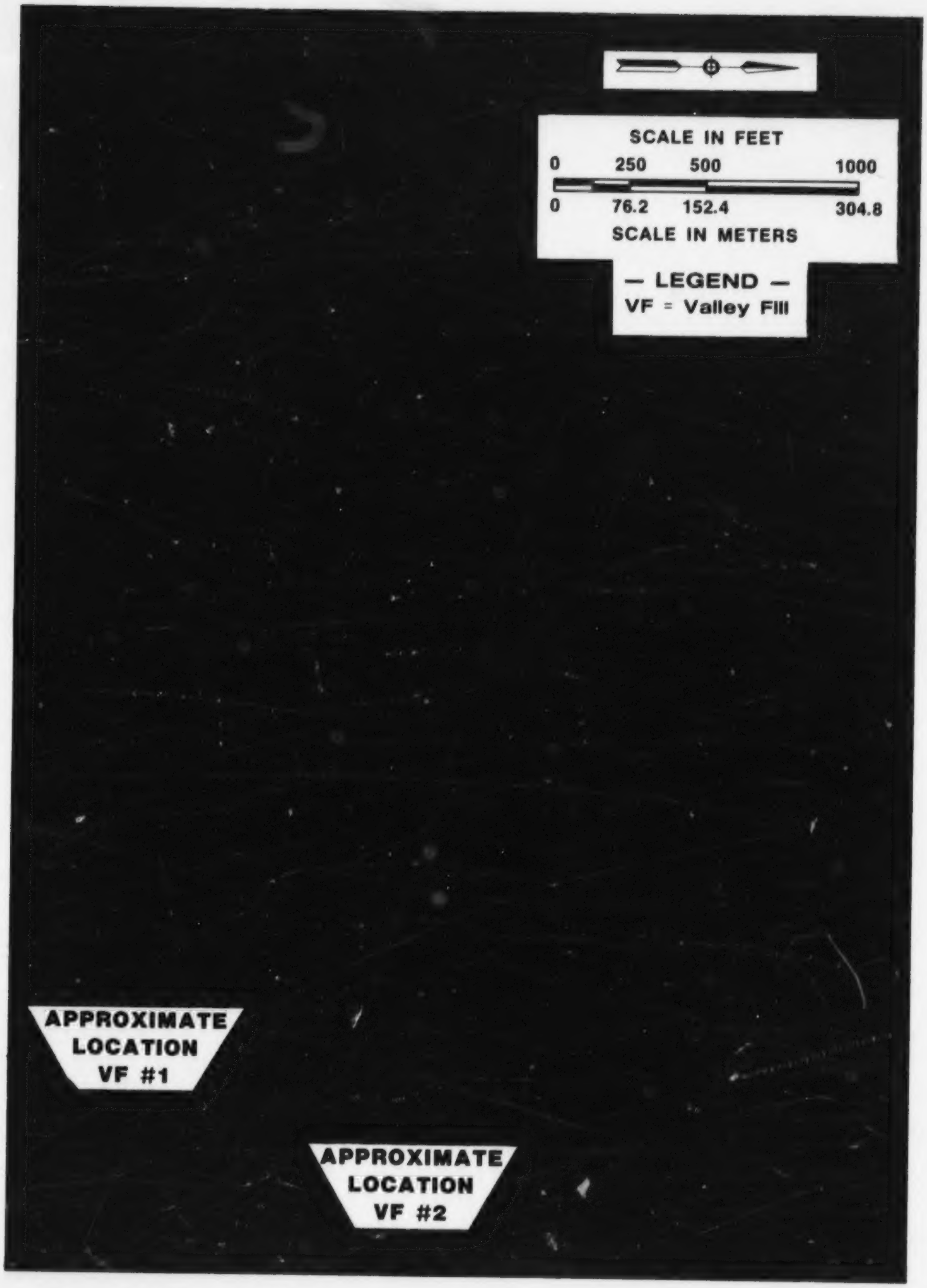

SCALE IN FEET
0
250
500
1000
0
76.2
152.4
304.8
SCALE IN METERS
— LEGEND —
VF = Valley Fill
APPROXIMATE LOCATION VF #1
APPROXIMATE LOCATION VF #2

Figure 16. Intensive site WV-07-SA aerial photo - Nov. 1976.

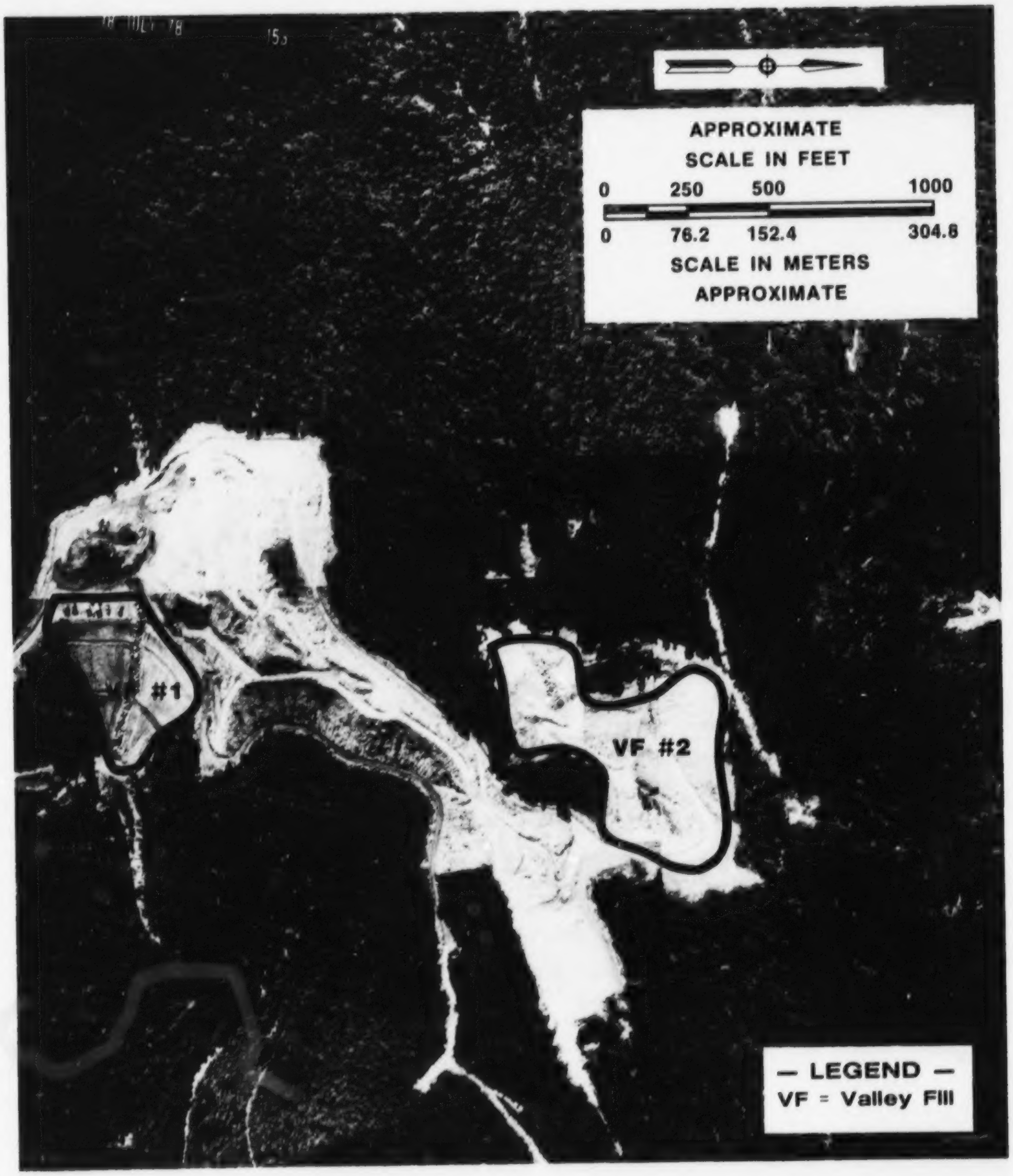
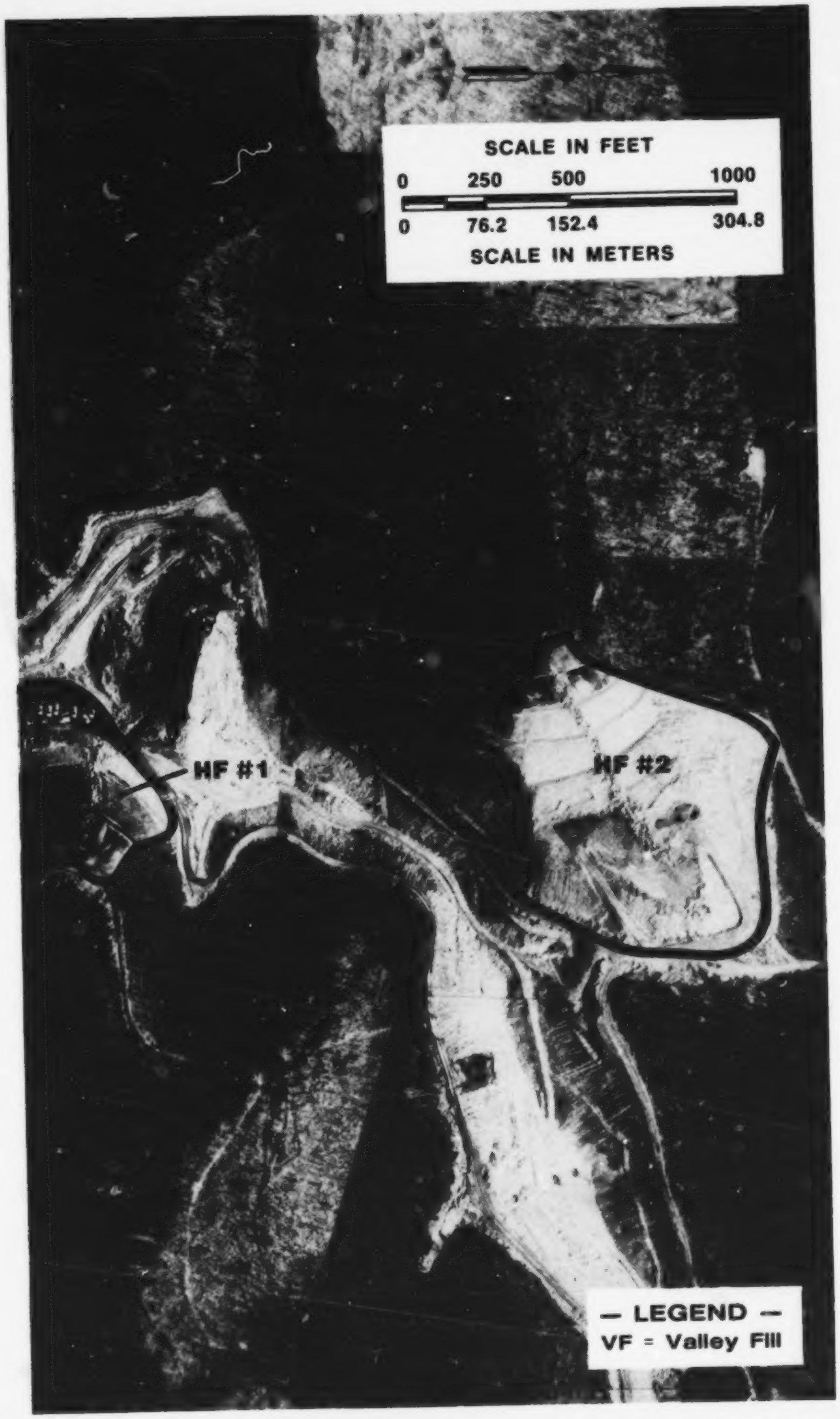

APPROXIMATE
SCALE IN FEET
0
250
500
1000
0
76.2
152.4
304.8
SCALE IN METERS
APPROXIMATE
VF #1
VF #2
— LEGEND —
VF = Valley Fill

Figure 17. Intensive site WV-07-SA aerial photo - July 1978.


SCALE IN FEET
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250
500
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0
76.2
152.4
304.8
SCALE IN METERS
HF #1
HF #2
— LEGEND —
VF = Valley Fill

Figure 18. Intensive site WV-07-SA aerial photo - Dec. 1978.

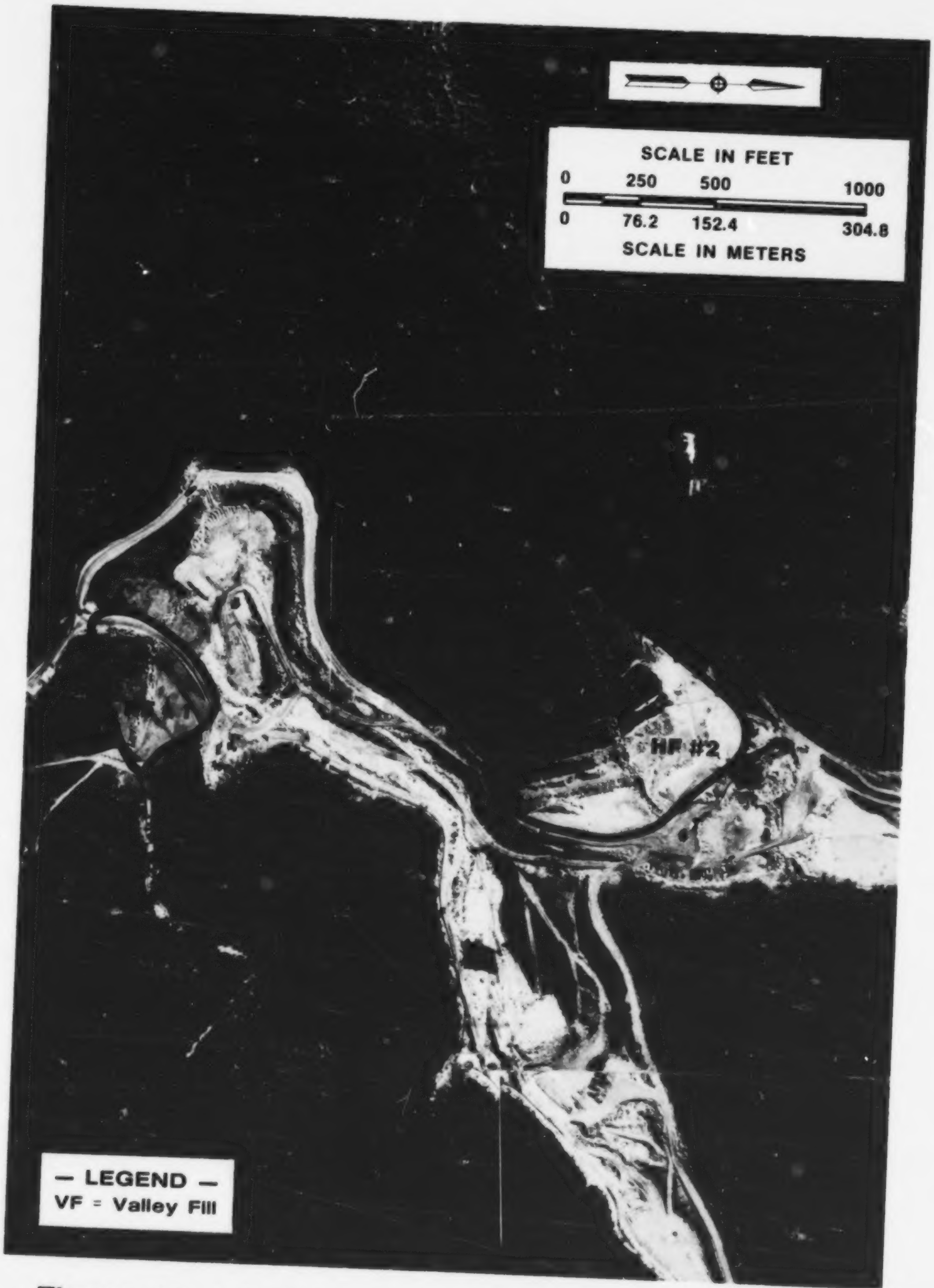

SCALE IN FEET
0
250
500
1000
0
76.2
152.4
304.8
SCALE IN METERS
HF #2
— LEGEND —
VF = Valley Fill

Figure 19. Intensive site WV-07-SA aerial photo - Sept. 1979.

located in the center of the stream at the point located on Figure 20 downstream of the toe of the hollow fill. The flume was set in place with sand bags to direct the stream flow through the flume. A Stevens Model 61R Total Flow Meter was used to monitor the water level in the flume. In October 1976, the monitoring station was destroyed by a flash flood. In March 1977, the station was reconstructed and made operational from March 1977. Until May 1978, the station operated erratically due to equipment difficulties. Due to the small size of the watershed and the steep slopes, high velocity and peak flows of the surface runoff caused the monitoring equipment to cease functioning several times. Finally, a severe rainfall event triggered another flash flood which destroyed the monitoring station in May 1978. In June 1978, a concrete structure was installed in place of the sandbag arrangement. The flow recorder was reinstalled and the station was once again made operational. In order to protect the monitoring station, a log and pole structure was constructed approximately ten meters (33 feet) upstream to aid in reducing the velocity of the stream during storm runoff periods.

During the study period, hydrographs for only two storm events were recorded due to the severe operational difficulties previously described. Rainfall data for the study area were obtained from the National Weather Service rain gauge nearest to the study watershed. Rainfall, runoff, and percent of runoff data for the two recorded storm events are listed in Table 16. Monthly rainfall data for the study period are listed in Table 17.

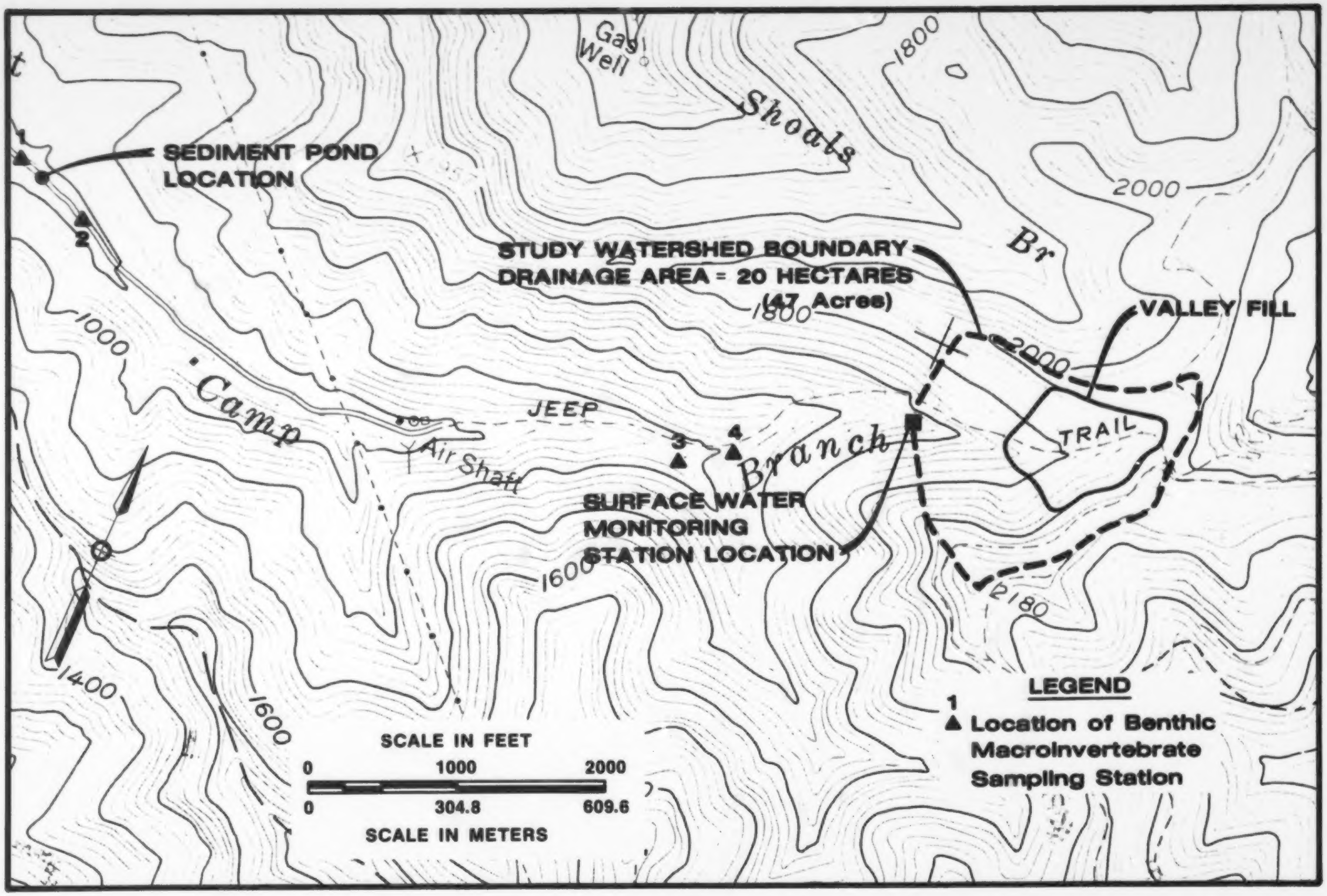
TABLE 16. RAINFALL/RUNOFF FOR WEST VIRGINIA STUDY WATERSHED

Date	Rainfall		Runoff		% Runoff
	cm	in	cm	in	
12/5-6/77	3.40	1.34	1.22	0.48	35.8
1/24-26/78	4.85	1.91	4.55	1.79	93.7

Hydrographs for the two storm events are included in Appendix D. The extremely high runoff for the January 1978 storm is due to a frozen ground cover resulting in nearly total runoff.

Water Quality

Water quality monitoring for the study watershed began in September 1976 after installation of the surface water monitoring station. An ISCO model 1680 automatic water sampler was installed at the previously described station in conjunction with the Parshall flume and Stevens Total Flow Meter. The ISCO water sampler contains 28 sample bottles and can be set for composite or discrete sampling based upon time or flow volume. For this installation, the water sampler was set to sample every six hours and to composite four samples into one container. The end result was a



t
1
SEDIMENT POND
LOCATION
2
Gas
Well
Shoals
1800
2000
Br
STUDY WATERSHED BOUNDARY
DRAINAGE AREA = 20 HECTARES
(47 Acres)
1800
VALLEY FILL
2000
1000
Camp
JEEP
3
4
Branch
TRAIL
Air Shaft
SURFACE WATER
MONITORING
STATION LOCATION
1600
2180
1400
1600
SCALE IN FEET
0
1000
2000
0
304.8
609.6
SCALE IN METERS
LEGEND
1
▲ Location of Benthic
Macroinvertebrate
Sampling Station

Figure 20. Monitoring station locations - intensive site WV-07-SA.

TABLE 17. MONTHLY RAINFALL MEASURED AT KOPPERSTON, WV 1976-1979

Month	1976 (cm)	1976 (in)	1977 (cm)	1977 (in)	1978 (cm)	1978 (in)	1979 (cm)	1979 (in)
January			7.4	2.9	17.5	6.9	23.1	9.1
February			3.6	1.4	5.8	2.3	N/A	N/A
March			4.8	1.9	7.6	3.0	11.9	4.7
April			19.6	7.7	13.0	5.1	12.4	4.9
May	6.6	2.6	3.8	1.5	15.7	6.2	18.0	7.1
June	10.4	4.1	12.7	5.0	5.8	2.3	21.3	8.4
July	10.2	4.0	14.7	5.8	12.2	4.8	20.1	7.9
August	7.1	2.8	18.5	7.3	19.1	7.5	14.7	5.8
September	15.2	6.0	6.1	2.4	5.3	2.1	12.2	4.8
October	18.3	7.2	15.5	6.1	3.8	1.5		
November	2.8	1.1	13.0	5.1	7.6	3.0		
December	9.7	3.8	8.6	3.4	24.1	9.5		

SOURCE: National Oceanic and Atmospheric Administration

daily composite sample. These daily samples were collected by a field technician and seven daily samples were composited based upon flow measurements to constitute a weekly composite sample. The weekly composite samples were transported to the laboratory for analysis. In the laboratory, a further composite was made of the weekly samples to produce a composite sample based upon a calendar month.

Unfortunately, delays in the mining schedule at this site resulted in longer time periods of pre-mining and active mining monitoring than were initially anticipated. Consequently, the originally planned program of 30 months of monitoring, although augmented by an additional 3 months, expired in June 1979, before mining was completed. Therefore, no post-mining monitoring data could be generated at this site.

Forty-one weekly composite water quality samples were collected upstream (influent) of the planned location of the sedimentation pond before initiation of mining. Fifteen such samples were collected at this location after mining began. Each sample was analyzed for the following parameters following the method listed:

Parameter	Method
pH	*APHA 221
Total Alkalinity	APHA 201
Hot Acidity	APHA 201
Turbidity	APHA 232
Total Solids	APHA 224
Total Iron	**EPA
Sulfate	APHA 156

*Standard Methods for the Examination of Water and Wastewater. 1975. 14th edition. APHA-AWWA-WPCF.

**Manual of Methods for Chemical Analysis of Water and Wastes. 1974. EPA-625/6-74-003. U.S. Environmental Protection Agency, Washington, D.C.

Means, standard deviations, and ranges calculated for these parameters are shown in Table 18. Individual sample data are presented in Appendix E. Figure 21 depicts the relative changes in water quality during the study period.

After the sedimentation pond was constructed, thirty-three weekly grab water quality samples were collected from the effluent. Each sample was analyzed for turbidity and suspended solids. Means, standard deviations, and ranges measured for these parameters are shown in Table 19. Individual sample data are presented in Appendix E.

Subsamples of the above weekly samples collected at both locations were composited on a calendar month basis. Each monthly composite was analyzed for all the above parameters plus the following: conductivity, calcium, magnesium, manganese, dissolved iron, aluminum, copper, zinc, cadmium, and nickel. Specific conductivity was measured following Standard Methods (APHA 226) and the metals were determined by atomic absorption spectrophotometer methods specified by EPA. Means, standard deviations, and ranges measured for these parameters are shown in Tables 20 and 21. Individual sample data are presented in Appendix E.

Changes in quality of water leaving the mine site after initiation of mining are evident in weekly composite sample measurements (Table 18). As would be expected, the pH values dropped slightly , and turbidity (280.5 to 547.3 JTU), total solids (674.4 to 2123.8 mg/l), total iron (2.9 to 14.9 mg/l), and sulfate (34.3 to 93.9 mg/l) increased. Monthly composite samples (Table 20) indicated that conductivity (250.0 to 415.5 µmhos/cm), calcium (21.5 to 37.8 mg/l), magnesium (13.6 to 24.4 mg/l), and aluminum (4.0 to 12.3 mg/l) also increased while the trace metals copper, zinc, cadmium, and nickel remained nearly the same or declined.

TABLE 18. WATER QUALITY DATA (MEANS, STANDARD DEVIATIONS AND RANGES) OF WEEKLY COMPOSITE SAMPLES COLLECTED UPSTREAM OF THE SEDIMENTATION POND AT INTENSIVE SITE WV-07-SA DURING THE PRE-MINING AND ACTIVE MINING PERIODS

Period	Number of Samples	Statistic	pH	Total alkalinity (mg/l $CaCO_3$)	Hot acidity (mg/l $CaCO_3$)	Turbidity (JTU)	Total solids (mg/l)	Total iron (mg/l)	Sulfate (mg/l)
Pre-mining	41	Mean		27.0	2.3	280.5	674.4	2.9	34.3
		Std. Dev.		10.4	37.1	730.9	730.1	5.2	45.4
		Range	4.8-7.2	16-54	-86-114	3-4250	65-2950	0.0-28.0	2-298
Active mining	15	Mean		32.6*	-18.9*	514.9	2123.8	14.9	93.9
		Std. Dev.		17.4	39.6	1062.9	1996.2	15.5	250.9
		Range	4.5-7.3	13-71	-82-41	4-4079	22-6219	0.0-50.4	13-1000

*Measured on 8 samples only.

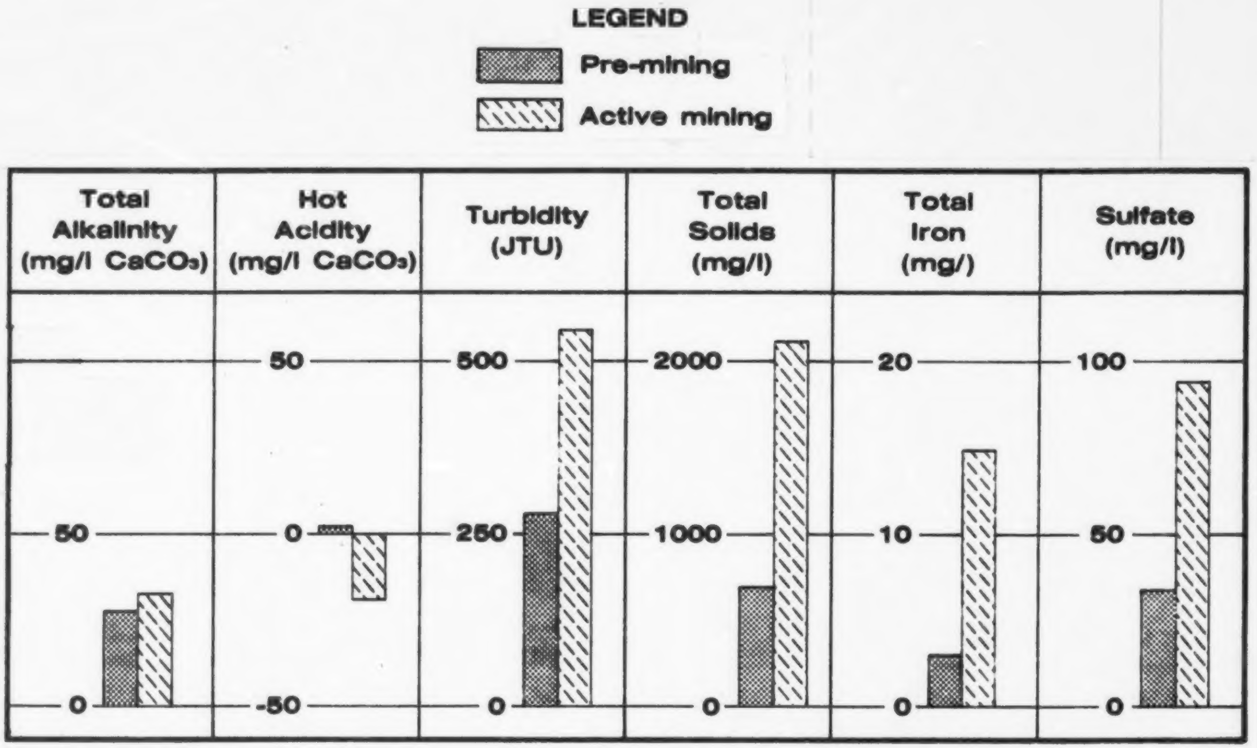


Figure 21. Water quality changes during mining at intensive site WV-07-SA.

TABLE 19. WATER QUALITY DATA (MEANS, STANDARD DEVIATIONS AND RANGES) OF WEEKLY GRAB SAMPLES COLLECTED AT THE EFFLUENT OF THE SEDIMENTATION POND AT INTENSIVE SITE WV-07-SA DURING THE ACTIVE MINING PERIOD

Number of Samples	Statistic	Turbidity (JTU)	Suspended solids* (mg/l)
33	Mean	113	936
	Std. Dev.	205	1382
	Range	1-870	13-3252

*Measured on 8 samples only.

Water samples were collected much more frequently above (influent) than below (effluent) the sedimentation pond, every 6 hours versus weekly. However, comparison of values measured above (influent) and below (effluent) the sedimentation pond allow approximation of its efficiency as an instrument of water quality improvement during active mining (Tables 20 and 21). Turbidity (450.3 to 54.4 JTU) and total solids (3306.2 to 755.3 mg/l) were substantially reduced in the water by its passage through the pond. Total iron (16.6 to 1.9 mg/l), aluminum (12.3 to 3.8 mg/l), and copper (0.05 to 0.02 mg/l) also decreased. However, conductivity (415.5 to 678.6 µmhos/cm), sulfate (190.5 to 408.0 mg/l), calcium (37.8 to 62.3 mg/l), and magnesium (24.4 to 41.8 mg/l) increased.

In conclusion, the quality of water leaving the mine site decreased, most notably in terms of turbidity, total solids, total iron, aluminum, and sulfate. However, passage of the water through the sedimentation pond appeared to substantially reduce these parameters with the exception of sulfate.

Stream Benthic Macroinvertebrate Community

Samples of the benthic macroinvertebrate community present in the stream receiving runoff from Intensive Site WV-07-SA were collected during the pre-mining period on May 12, 1977 and during the period of active mining on November 9, 1978, September 15, 1979, and April 23, 1980. Four sample stations were established on this stream at distances 0.4 km (0.2 miles), 1.5 km (0.9 miles), 2.2 km (1.4 miles), and 2.7 km (1.7 miles) from confluence with the Guyandotte River (Figure 20). Three replicate Surber (net mesh opening = 1.02 mm) samples were collected at each station on the first sample date. However, lack of stream current, essential to proper operation of the Surber sampler, permitted collection of samples only at the two most downstream stations on the subsequent sample dates.

A detailed physical survey conducted September 15, 1979 indicated that conditions were slightly different at stations 1 and 2 (Table 22).

TABLE 20. WATER QUALITY DATA (MEANS, STANDARD DEVIATIONS AND RANGES) OF MONTHLY COMPOSITE SAMPLES COLLECTED AT THE INFLUENT OF THE SEDIMENTATION POND AT INTENSIVE SITE WV-07-SA DURING THE PRE-MINING AND ACTIVE MINING PERIODS

Parameter	Pre-mining			Active mining		
	Mean	Std. Dev.	Range	Mean	Std. Dev.	Range
pH			6.5-7.4			5.9-6.6
Total alkalinity (mg/l $CaCO_3$)	33.0	30.7	0-128	66.0	62.2	22-110
Hot acidity (mg/l $CaCO_3$)	18.0	47.7	-26-160	-0.5	7.7	-6-5
Turbidity (JTU)	160.8	139.8	<5-400	450.3	336.9	48-964
Total solids (mg/l)	20638.0	55366.8	70-195000	3306.2	2447.6	180-6363
Suspended solids (mg/l)	20353.7	55145.9	7-194000	3144.0	4310.5	96-6192
Conductivity (µmhos/cm)	250.0	354.5	85-1380	415.5	651.0	80-1740
Sulfate (mg/l)	45.9	47.9	20-190	190.5	401.7	15-1010
Calcium (mg/l)	21.5	27.1	7-110	37.8	59.2	4-158
Magnesium (mg/l)	13.6	25.8	4-99	24.4	41.1	4-108
Manganese (mg/l)	2.9	7.3	0.0-27.0	2.8	2.8	0.2-7.9

(continued)

TABLE 20. (continued)

Parameter	Pre-mining Mean	Pre-mining Std. Dev.	Pre-mining Range	Active mining Mean	Active mining Std. Dev.	Active mining Range
Total iron (mg/l)	7.5	14.8	0.0-55.6	16.6	11.0	1.6-29.4
Dissolved iron (mg/l)	0.1	0.1	0.0-0.4	N/A	N/A	N/A
Aluminum (mg/l)	4.0	6.0	<0.1-22.5	12.3	7.6	1.6-18.9
Copper (mg/l)	0.07	0.21	<0.01-0.78	0.05	0.02	0.01-0.07
Zinc (mg/l)	0.30	0.64	0.02-2.40	0.21	0.23	0.03-0.66
Cadmium (mg/l)	0.01	0.01	<0.01-0.01	0.01	0.01	<0.01-0.03
Nickel (mg/l)	0.10	0.26	<0.03-0.98	0.11	0.14	<0.03-0.39

Number of samples: Pre-mining - 13
Active mining - 6 (except pH, hot acidity, and suspended solids - 2 samples only)

TABLE 21. WATER QUALITY DATA (MEANS, STANDARD DEVIATIONS AND RANGES) OF MONTHLY COMPOSITE SAMPLES COLLECTED AT THE EFFLUENT OF THE SEDIMENTATION POND AT INTENSIVE SITE WV-07-SA DURING THE ACTIVE MINING PERIOD

Parameter	Mean	Std. Dev.	Range
Turbidity (JTU)	54.4	49.5	0-130
Total solids (mg/l)	755.3	763.7	130-2042
Conductivity (µmhos/cm)	678.6	753.3	145-1842
Sulfate (mg/l)	408.0	522.6	46-1200
Calcium (mg/l)	62.3	69.6	14-169
Magnesium (mg/l)	41.8	49.6	7-118
Manganese (mg/l)	3.3	4.9	0.1-13.2
Total iron (mg/l)	1.9	2.8	0.1-8.6
Aluminum (mg/l)	3.8	5.5	<0.01-14.4
Copper (mg/l)	0.02	0.01	<0.01-0.04
Zinc (mg/l)	0.22	0.30	<0.01-0.73
Cadmium (mg/l)	<0.01	0.00	all <0.01
Nickel (mg/l)	0.14	0.17	<0.03-0.43

Number of samples: 8.

TABLE 19. WATER QUALITY DATA (MEANS, STANDARD DEVIATIONS AND RANGES) OF WEEKLY GRAB SAMPLES COLLECTED AT THE EFFLUENT OF THE SEDIMENTATION POND AT INTENSIVE SITE WV-07-SA DURING THE ACTIVE MINING PERIOD

Number of Samples	Statistic	Turbidity (JTU)	Suspended solids* (mg/l)
33	Mean	113	936
	Std. Dev.	205	1382
	Range	1-870	13-3252

*Measured on 8 samples only.

Water samples were collected much more frequently above (influent) than below (effluent) the sedimentation pond, every 6 hours versus weekly. However, comparison of values measured above (influent) and below (effluent) the sedimentation pond allow approximation of its efficiency as an instrument of water quality improvement during active mining (Tables 20 and 21). Turbidity (450.3 to 54.4 JTU) and total solids (3306.2 to 755.3 mg/l) were substantially reduced in the water by its passage through the pond. Total iron (16.6 to 1.9 mg/l), aluminum (12.3 to 3.8 mg/l), and copper (0.05 to 0.02 mg/l) also decreased. However, conductivity (415.5 to 678.6 mhos/cm), sulfate (190.5 to 408.0 mg/l), calcium (37.8 to 62.3 mg/l), and magnesium (24.4 to 41.8 mg/l) increased.

In conclusion, the quality of water leaving the mine site decreased, most notably in terms of turbidity, total solids, total iron, aluminum, and sulfate. However, passage of the water through the sedimentation pond appeared to substantially reduce these parameters with the exception of sulfate.

Stream Benthic Macroinvertebrate Community

Samples of the benthic macroinvertebrate community present in the stream receiving runoff from Intensive Site WV-07-SA were collected during the pre-mining period on May 12, 1977 and during the period of active mining on November 9, 1978, September 15, 1979, and April 23, 1980. Four sample stations were established on this stream at distances 0.4 km (0.2 miles), 1.5 km (0.9 miles), 2.2 km (1.4 miles), and 2.7 km (1.7 miles) from confluence with the Guyandotte River (Figure 20). Three replicate Surber (net mesh opening = 1.02 mm) samples were collected at each station on the first sample date. However, lack of stream current, essential to proper operation of the Surber sampler, permitted collection of samples only at the two most downstream stations on the subsequent sample dates.

A detailed physical survey conducted September 15, 1979 indicated that conditions were slightly different at stations 1 and 2 (Table 22).

TABLE 22. PHYSICAL SURVEY OF BENTHIC MACROINVERTEBRATE SAMPLE STATIONS ON THE STREAM RECEIVING RUNOFF FROM INTENSIVE SITE WV-07-SA CONDUCTED SEPTEMBER 15, 1979

Parameter	Station 1	Station 2
Mean Depth, cm (in)	15 (6)	6 (2)
Mean Width, cm (in)	92 (36)	65 (26)
Mean Current Velocity, m/sec (ft/sec)	0.2 (0.7)	0.3 (1.0)
Substrate Type	Sand, gravel, and stones to 30 cm (12 in) diameter	Sand, gravel, and stones to 15 cm (6 in) diameter
Water Temperature, C(°F)	18 (64)	16 (61)

Mean width at station 1 was 92 cm (36 in) and at station 2 was 65 cm (26 in). Mean water depth at station 1 was 15 cm (6 in) and at station 2 was 6 cm (2 in). Mean current velocity was somewhat greater at station 2, 0.3 m/sec (1.0 ft/sec), than at station 1, 0.2 m/sec (0.7 ft/sec). Water temperature at station 1, 18 C (64 F), was slightly higher than at station 2, 16 C (61 F), reflecting input of warmer water from the sedimentation pond approximately 49 m (160 ft) upstream of station 1. Although the stream substrate at both stations contained sand and gravel, rocks with diameter to 30 cm (12 in) were present at station 1, whereas the diameter of rocks present at station 2 did not exceed 15 cm (6 in). Leaf packets were present in the substrate at both stations. The surrounding environment at each station was wooded, although a small open area and the sedimentation pond were present near station 1.

Each replicate sample was preserved in formalin and transported to the laboratory for processing. All macroinvertebrate specimens were sorted from sample residue without flotation, stain, or magnification aid. Using a dissection microscope all specimens were identified to the lowest practicable taxon (family, genus, or species). Mean numerical density per square meter was calculated for each taxon. The standard error of the mean was calculated for each sample collected November 9, 1978, September 15, 1979, and April 23, 1980. Each standard error was expressed as a percentage of the corresponding sample mean to indicate the amount of error in the sample mean when it was used to estimate the population mean. All values were below (10.8%, 24.2%, 30.9%, 35.3%, 39.6%) or exceeded very slightly (40.4%) the recommended acceptable standard error (40.0%) in benthic macroinvertebrate sampling (Cummins 1975).

In addition to estimating macroinvertebrate numerical densities, all specimens collected November 9, 1978, September 15, 1979, and April 23, 1980 were weighed to provide total biomass density estimates. The specimens were dried in an oven at 100°C (212°F) for 24 hours, allowed to cool to room temperature in a dessicator, and weighed with a Mettler balance, model #54AR.

Macroinvertebrate species composition (Tables 23-26) varied among stations (spatially) and dates (temporally). More total taxa (all stations combined) were collected May 12, 1977 (22) than were collected November 9, 1978 (12), September 15, 1979 (9), or April 23, 1980 (14). More taxa were collected upstream (station 2) than downstream (station 1) on the first two sample dates. The relative positions were reversed on the latter sample dates.

Total numerical density (all taxa and all stations combined, individuals/m^2) was lowest May 12, 1977 (218.4) and nearly equal November 9, 1978 (528.9), September 15, 1979 (537.5), and April 23, 1980 (531.7). Total numerical density (all taxa combined) at individual stations was greater at station 2 all sample dates. Numerically dominant taxa and densities recorded (individuals/m) were Naididae (123.0), *Chloroperla* sp. (22.5), Chironomidae (18.0), and *Cheumatopsyche* sp. (14.4) May 12, 1977; Chironomidae (394.8), Naididae (64.6), and *Nemoura* sp. (36.1) November 9, 1978; Chironomidae (359.2), *Baetis* sp. (120.6), and *Diplectrona* sp. (28.6) September 15, 1979; and *Baetis* sp. (384.0), *Hydropsyche* sp. (53.7), and *Cheumatopsyche* sp. (23.2) April 23, 1980.

Mean macroinvertebrate biomass (all stations combined, g/m) increased through the sample dates. The increase was particularly substantial between September 15, 1979 and April 23, 1980 (1006.6%) and may be due, at least in part, to collection of more mature (larger) specimens in spring than in late summer. Mean macroinvertebrate biomass was substantially less at station 1 relative to station 2 November 9, 1978. However, the percentage difference was reduced September 15, 1979 and on April 23, 1980 mean macroinvertebrate biomass at station 1 exceeded that at station 2.

In general, this stream supported a macroinvertebrate community at each station containing small numbers of individuals distributed among a few taxa, with Chironomidae numerically dominant on several sample dates. This rather simple community structure is not uncommon in streams undergoing chemical or physical stress. Dominance of Chironomidae also is not unusual. This group is well known for its wide range of environmental tolerance (Beck 1977).

The lower population densities at station 1 relative to the other stations observed uniformly through the sample dates may be the result of a combination of factors. The presence of larger rocks in the substrate at station 1 relative to station 2 may result in subtle differences in interstitial microhabitat available for macroinvertebrate colonization. Furthermore, the possible presence of an unknown stress factor introduced into the stream below station 2, perhaps from the sedimentation pond or in

TABLE 23. BENTHIC MACROINVERTEBRATE DATA FROM SAMPLES COLLECTED IN THE STREAM RECEIVING RUNOFF FROM INTENSIVE SITE WV-07-SA MAY 12, 1977

Taxon	Mean numerical density (No/m^2)				
	Station 1	Station 2	Station 3	Station 4	All stations
Oligochaeta					
Naididae		491.8			123.0
Decapoda					
Astacidae		3.6		3.6	0.9
Plecoptera					
Acroneuria sp.				3.6	0.9
Chloroperla sp.	14.6	17.9	35.9	21.5	22.5
Leuctra sp.			3.6		0.9
Perlodidae			21.5		5.4
Ephemeroptera					
Ameletus sp.	7.2	7.2			3.6
Ephemerella sp.			7.2	3.6	2.7
Paraleptophlebia sp.	3.6			3.6	1.8
Stenonema sp.		3.6		10.8	3.6
Unknown				3.6	0.9
Hemiptera					
Hebrus sp.				10.8	2.7
Trichoptera					
Cheumatopsyche sp.			57.4		14.4
Psychomyiidae			3.6	3.6	1.8
Rhyacophila sp.				3.6	0.9
Coleoptera					
Ectopria sp.			7.2	14.4	5.4
Macronychus sp.				3.6	0.9
Psephenus sp.				3.6	0.9
Diptera					
Bezzia sp.		10.8	10.8		5.4
Chironomidae	7.2	35.9	25.1	3.6	18.0
Eriocera sp.	3.6				0.9
Tipulidae		3.6			0.9
All Taxa	36.2	574.4	172.3	93.5	218.4
Total Taxa Collected	5	8	9	14	22

TABLE 24. BENTHIC MACROINVERTEBRATE DATA FROM SAMPLES COLLECTED IN THE STREAM RECEIVING RUNOFF FROM INTENSIVE SITE WV-07-SA NOVEMBER 9, 1978

Taxon	Mean numerical density (No/m^2)		
	Station 1	Station 2	All Stations
Oligochaeta			
Naididae		129.2	64.6
Plecoptera			
Nemoura sp.		72.2	36.1
Ephemeroptera			
Baetis sp.		24.8	12.4
Trichoptera			
Cheumatopsyche sp.		3.2	1.6
Diplectrona sp.		3.2	1.6
Philopotamidae		7.5	3.8
Psychomyiidae		3.2	1.6
Diptera			
Brachydeutera sp.		3.2	1.6
Ceratopogonidae		7.5	3.8
Chironomidae	53.9	735.6	394.8
Dixidae		10.8	5.4
Tipula sp.		3.2	1.6
All Taxa	53.9	1003.6	528.9
Standard Error (SE)	19.0	397.0	--
SE as % of Total Number	35.3%	39.6%	--
Total Taxa Collected	1	12	12
Mean Biomass (g/m^2)	0.00944	0.04836	0.02890

TABLE 25. BENTHIC MACROINVERTEBRATE DATA FROM SAMPLES COLLECTED IN THE STREAM RECEIVING RUNOFF FROM INTENSIVE SITE WV-07-SA SEPTEMBER 15, 1979

Taxon	Mean numerical density (No/m^2)		
	Station 1	Station 2	All Stations
Plecoptera			
Nemoura sp.	7.5	7.5	7.5
Peltoperla sp.	7.5		3.8
Ephemeroptera			
Baetis sp.	93.7	147.5	120.6
Trichoptera			
Cheumatopsyche sp.	10.8		5.4
Diplectrona sp.	3.2	53.9	28.6
Hydropsyche sp.	10.8	7.5	9.2
Neureclipsis sp.	3.2		1.6
Megaloptera			
Nigronia sp.	3.2		1.6
Diptera			
Chironomidae	32.3	686.1	359.2
All Taxa	172.2	902.5	537.5
Standard Error (SE)	53.2	364.5	---
SE as % of Total Number	30.9%	40.4%	---
Total Taxa Collected	9	5	9
Mean Biomass (g/m^2)	0.06925	0.11549	0.09237

abandoned mine drainage, may adversely affect the community at station 1. It is noteworthy, however, that disparity in mean numerical density between stations 1 and 2 decreased through the sample dates, as did the difference in mean biomass.

It is difficult to conclude adverse impact of the surface mining within this stream's watershed. Although fewer macroinvertebrate species were collected in the stream after initiation of mining, those species present included groups traditionally considered sensitive to environmental perturbation, mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera). Furthermore, macroinvertebrate numerical densities increased after mining began. It must be noted, too, that the structure of macroinvertebrate communities is inherently dynamic and not well understood. What may be loosely interpreted as community change due to adverse mining impact, may in fact be in response to unrecognized stimuli.

Terrestrial Vegetation

Several surveys were conducted at Intensive Site WV-07-SA to describe the herbaceous and woody components of the terrestrial vegetation

TABLE 26. BENTHIC MACROINVERTEBRATE DATA FROM SAMPLES COLLECTED IN THE STREAM RECEIVING RUNOFF FROM INTENSIVE SITE WV-07-SA APRIL 23, 1980

Taxon	Mean numerical density (No/m^2)		
	Station 1	Station 2	All Stations
Plecoptera			
Amphinemura sp.	18.0		9.0
Unknown sp.	7.2		3.6
Ephemeroptera			
Baetis sp.	269.3	498.7	384.0
Epeorus sp.	21.5		10.8
Ephemerella sp.	7.2	10.8	9.0
Stenonema sp.		3.2	1.6
Trichoptera			
Cheumatopsyche sp.	35.5	10.8	23.2
Diplectrona sp.	3.2	10.8	7.0
Hydropsyche sp.	24.8	82.6	53.7
Megaloptera			
Sialis sp.	3.2		1.6
Diptera			
Chironomidae	7.2	18.0	12.6
Empididae	3.2		1.6
Pedicia sp.	3.2		1.6
Tipula sp.	14.0	10.8	12.4
All Taxa	417.5	645.7	531.7
Standard Error (SE)	45.1	156.2	--
SE as % of Total Number	10.8	24.2	--
Total Taxa Collected	13	8	14
Mean Biomass (g/m^2)	0.989689	0.87276	0.92983

prior to disruption by mining. Herbaceous vegetation (wildflowers and shrubs) was studied June 1977 and May 1978. Woody vegetation (trees) was studied May 1977.

On the herbaceous vegetation study dates, specimens were collected, preserved, and transported to the laboratory for identification. Taxonomy is that of Strausbaugh and Core (1970, 1971, 1973, 1977), a series of keys to the vegetation of West Virginia.

Twenty-nine herbaceous species were identified both sample dates, including ferns, shrubs, and wildflowers (Table 27). With exception of four species, *Taraxacum officinale* (Common Dandelion), *Typha latifolia* (Broad-leaved Cattail), *Vicia caroliniana* (Wild Vetch), and *Viola hirsutula* (Southern Wood Violet) not collected July 1977, all species were collected both sample dates.

Seventeen species were identified in a sample of 100 trees numerically dominated by 26 Chestnut Oaks (*Quercus prinus*) and 13 Blackgums (*Nyssa sylvatica*) (Table 28). The Chestnut Oaks were much larger trees because their total basal area or trunk cross-sectional area, 47567.5 cm^2 (7374.8 in^2), greatly exceeded that of the Blackgums, 7162.7 cm^2 (1110.5 in^2) (Table 29). The total basal area of all trees observed was 89373.1 cm^2 (13856.3 in^2) and the mean distance measured between trees was 5.3 m (17.5 ft). With mean canopy area of an individual tree 28.2 m^2 (305.3 ft^2), the density of trees was 57.4 trees/hectare (142.2 trees/acre). Importance value, a numerical quantity calculated for each species incorporating the number of individuals, the total basal area, and the relative frequency of occurrence, was greatest for Chestnut Oaks (101.45%) and Blackgums (34.34%).

Data for individual pairs of trees are presented in Appendix F.

TABLE 27. HERBACEOUS SPECIES COLLECTED AT INTENSIVE SITE WV-07-SA JUNE 1977 AND MAY 1978

Scientific Name	Common Name
Arisaema stewardsonii	Jack-in-the-pulpit
Clintonia umbellulata	White Clintonia
Duchesnea indica	Indiana Strawberry
Erythronium albidum	White Fawn Lilly
Geranium maculatum	Wild Geranium
Heuchera americana	Alumroot
Hypoxis hirsuta	Yellow Stargrass
Oxalis grandis	Great Yellow Wood Sorrel
Podophyllum peltatum	May-apple
Polystichum acrostichoides	Christmas Fern
Potentilla canadensis	Canada Cinquefoil
P. simplex	Common Cinquefoil
Pteridium aquilinum	Bracken Fern
Rhododendron calendulaceum	Flame Azalea
R. roseum	Rose Azalea
Sambucus sp.	Elderberry
Sedum ternatum	Wild Stonecrop
Silene virginica	Fire Pink
Senecio aureus	Golden Ragwort
Smilacina racemosa	False Solomon's Seal
Stellaria pubera	Great Chickweed
*Taraxacum officinale	Common Dandelion
Thalictrum dioicum	Early Meadowrue
Trillium grandiflorum	Large-Flowered Trillium
*Typha latifolia	Broad-leaved Cattail
Uvularia grandiflora	Large Flowered Bellwort
*Vicia caroliniana	Wild Vetch
*Viola hirsutula	Southern Wood Violet
V. pensylvanica	Smooth Yellow Violet

* Not collected June 1977.

TABLE 28. TREE SPECIES IDENTIFIED AND TOTAL NUMBER COUNTED IN SAMPLE PLOTS AT INTENSIVE SITE WV-07-SA MAY 1977

Scientific Name	Common Names	Number of Trees
Acer rubrum	Red Maple	5
Carya cordiformis	Bitternut Hickory	2
C. glabra	Pignut Hickory	7
C. ovata	Shagbark Hickory	4
Cornus florida	Flowering Dogwood	5
Liriodendron tulipifera	Yellow-poplar	6
Nyssa sylvatica	Black Gum	13
Pinus rigida	Pitch Pine	2
Pyrus sp.	Chokecherry	7
Quercus alba	White Oak	1
Q. coccinea	Scarlet Oak	7
Q. prinus	Chestnut Oak	26
Q. velutina	Black Oak	3
Q. sp.	Unidentified Oak Species	1
Robinia pseudo-acacia	Black Locust	2
Sassafras albidum	Sassafras	3
Tilia americana	Basswood	6
	Total	100

TABLE 29. SUMMARY OF TREE SPECIES DATA COLLECTED THROUGH RANDOM PAIRS SAMPLING AT INTENSIVE SITE WV-07-SA

	Relative density %	Relative dominance %	Frequency	Relative frequency %	Dominance	Importance value %	Basal area (cm^2)	Basal area (in^2)	Density Trees/ hectare	Density Trees/ acre
Basswood	6.00	3.98	0.10	5.56	551.5	15.54	3,554.0	551.0	3.4	8.5
Bitternut Hickory	2.00	1.92	0.04	2.22	266.0	6.14	1,720.2	266.7	1.1	2.8
Black Gum	13.00	8.01	0.24	13.33	1,109.9	34.34	7,162.7	1,110.5	7.5	18.5
Black Locust	2.00	0.47	0.04	2.22	65.1	4.69	422.5	65.5	1.1	2.8
Black Oak	3.00	7.05	0.06	3.33	976.9	13.38	6,300.4	976.8	1.7	4.3
Chestnut Oak	26.00	53.22	0.40	22.23	7,374.3	101.45	47,567.5	7,374.8	14.9	37.0
Chokecherry	7.00	3.18	0.14	7.78	440.6	17.96	2,838.6	440.1	4.0	10.0
Flowering Dogwood	5.00	1.18	0.08	4.44	163.5	10.62	1,053.9	163.4	2.9	7.1
Oak (unidentified species)	1.00	0.28	0.02	1.11	38.8	2.39	248.3	38.5	0.6	1.4
Pignut Hickory	7.00	5.41	0.14	7.78	749.6	20.19	4,834.9	749.6	4.0	10.0
Pitch Pine	2.00	1.77	0.04	2.22	245.3	5.99	1,583.5	245.5	1.1	2.8
Red Maple	5.00	0.73	0.10	5.56	101.2	11.29	648.9	100.6	2.9	7.1
Sassafras	3.00	0.54	0.06	3.33	74.8	6.87	483.8	75.0	1.7	4.3
Scarlet Oak	7.00	7.08	0.12	6.67	981.0	20.75	6,323.6	980.4	4.0	10.0
Shagbark Hickory	4.00	1.50	0.08	4.44	207.8	9.94	1,337.1	207.3	2.3	5.7
White Oak	1.00	0.72	0.02	1.11	99.8	2.83	646.9	100.3	0.6	1.4
Yellow-Poplar	6.00	2.96	0.12	6.67	410.1	15.63	2,649.7	410.8	3.4	8.5

Mean distance tree to tree: 5.3 m (17.5 ft.)

Total density: 57.4 trees/hectare (142.2 trees/acre)

Mean canopy area: 28.2 m^2 (306.3 ft^2)

Total basal area: 89,373.1 cm^2 (13,856.3 in^2)

SECTION 6
VALLEY FILL SUBSURFACE INVESTIGATIONS

Part of this assessment of the environmental effects of head-of-hollow fill (or valley fill) construction and mountaintop removal mining dealt with fill stability. This section is a description of an introductory investigation of the stability of three fills in Kentucky and West Virginia. The following subject areas were addressed: type of constituent material within the fills, degree of degradation the material has undergone, and internal drainage of the fills. Volume II presents the results of more detailed study of one fill that was part of the introductory investigation and several additional fills.

METHODS OF INVESTIGATION

Samples of constituent material were collected through use of a Becker Hammer, basically a low energy pile driver. This diesel operated machine was used to drive an 8.26 cm (3.25 in) ID casing into the overburden. As the casing was driven, cuttings were removed by a continuous high pressure air stream and collected in a cyclone dissipator and bucket. Samples of the cuttings were removed from the bucket.

Use of conventional split spoon samplers was unsatisfactory because of their small diameter relative to the size of particles contained in the fills. The coarse particles also prevented collection of undisturbed samples using thin wall Shelby tubes.

During drilling, distance from the surface was noted wherever ground water was encountered.

DESCRIPTION OF THE FILLS

One fill (BA) was located on a mountaintop removal mine in Logan County, WV. It was constructed in a valley with side slopes of 23° and an original ground slope of 6° at the toe of the fill. The fill contained 42,050,517 m^3. (55,000,000 yd^3) of principally sandstone spoil and covered an area of 30.2 hectares (74.5 acres). Benches were constructed approximately every 15.2 m (50 ft) vertically on the outside fill face. Maximum outslope of the final fill face was 26°. Erosion of the slopes was controlled by a surge pool located on the fill platform. Internal drainage was facilitated by a central rock core of fractured sandstone.

Visual inspection of Fill BA indicated that surface erosion was minor with only a few erosion scars. However, erosion at the interface of the fill sides and the hollow may be a problem. Nevertheless, the long-term outlook for fill stability was good, depending on continued function of the rock core drain.

Another fill (HA) was located in McDowell County, WV, also on a mountaintop removal mine. Side slopes of the valley where it was constructed were 26°. The original ground slope at the toe of the fill was 7°. The fill covered an area of 3.0 hectares (7.4 acres) and contained 152,911 m^3 (200,000 yd^3) of spoil. Maximum outslope of the final fill face was 26°. A surge pool constructed on the fill platform controlled erosion of the slopes. A central rock core of fractured shale received internal drainage.

Fill HA appeared to be in good condition with some small gullies on the outslope. Erosion at the interface of the fill sides and the hollow did not appear to be a problem. The surface of the rock core drain (shale) appeared to be weathering rapidly. The long-term outlook for fill stability was good, if the rock core drain did not erode and continued to function.

Another fill (LA) was located in Perry and Breathitt Counties, KY, on a contour strip mine. The environmental effects of construction of this fill were described in the preceding section of this report entitled "Eastern Kentucky Mine Site." This fill was 29 m (94 ft) in height with a length of 610 m (2,000 ft). The outslope was continuous (no benches) at an angle of 28°. No surge pool was constructed on the platform, nor was a rock core part of the design.

Surface erosion appeared to be a problem at Fill LA. Although the outslope was vegetated, several gullies were present. Two gullies were very large - one with a depth of 1.5 m (5 ft) and a width of 3 m (10 ft). No seepage was observed at the toe of the fill. However, inspection was made during a period of low precipitation. The long-term outlook for fill stability was good, if surface erosion did not increase.

RESULTS OF SUBSURFACE INVESTIGATIONS

The number of borings drilled at the fill locations were as follows:

Fill	No. of Borings
BA	3
HA	2
LA	3

The maximum depths penetrated were 17.5 m (57.5 ft), 14.6 m (48.0 ft), and 24.0 m (79.0 ft) at Fills BA, HA, and LA, respectively. The field logs indicated that all borings passed through the fills and penetrated underlying natural overburden. It was found that sandstone is the principal material in Fill BA, that there was a small amount of sandstone in Fill LA, and that Fill HA was almost entirely composed of shale. The density of the material in each of the fills was very high, as measured by the blow count data shown on the boring logs contained in Appendix G. Generally, the penetration resistance was greater than thirty blows per foot, indicative of high particle density.

The groundwater data showed that the fills were all well drained. It appeared that there may be a localized seepage area which created a saturated zone in Fill LA, as shown by the high moisture content in Boring No. LA-3. There was a pond near this boring location which was believed to be the seepage source.

The moisture content data, also shown on the boring logs, were generally less than 10%. The greatest values were in the aforementioned saturated zone of Boring No. LA-3 and where a stratum of natural soil was encountered immediately below the fill, Boring Nos. LA-2 and LA-3. The low moisture was to be expected, considering the coarse rock-like nature of the fill material.

CONCLUSIONS

The three fills investigated as a part of this study were composed of dense material which had not suffered substantial degradation. The groundwater information indicated that the fills were free draining and no water was ponding within the fills. The natural moisture content of the fill material was that expected for coarse grained material or the natural bedrock from which it was derived. Although no detailed analyses were performed on the geometry of the fills, the material comprising the fills, and the natural overburden conditions led to the conclusion that the fills were stable.

SECTION 7

FUGITIVE DUST EMISSIONS FROM APPALACHIAN SURFACE COAL MINES

Another phase of this study was to measure and compare fugitive dust emissions generated by mountaintop removal and contour surface mines in the Appalachian region. This section presents the results of fugitive dust monitoring programs conducted at several mountaintop removal and contour surface mines.

MINE DESCRIPTIONS

Fugitive dust emissions were sampled at three mining operations in Kentucky and West Virginia. All were located in areas of similar topography, steep erosion valleys and mountainous terrain, and climate, annual precipitation 102-122 cm (40-48 in).

The mountaintop removal mining operation sampled was located in McDowell county in south-central West Virginia. Two separate areas within the operation were mined simultaneously (Figure 22), with a total disturbed sampling area of 12.3 hectares (33 acres). Sampling was conducted at both areas, designated as Mines #1 and #2. The major soil association present was the Muskingum, shallow to moderately deep, well-drained, and derived from acidic sandstone and shale. Two coal seams were mined, the Sewell and the Welch, with 46 m (150 ft) of overburden removed. The overburden was drilled, blasted, excavated, loaded with front-end loaders onto trucks, and hauled 0.8 km (0.5 miles) to a head-of-hollow fill. Coal was similarly loaded, but was hauled 3.2 km (2 miles) to a preparation plant. Regrading was accomplished by bulldozer and reclaimed land was revegetated by hydroseeder. The mines employed a total of 40 people working two 9-hour shifts per day, 6 days per week. Average daily coal production was 910 metric (1000 short) tons per day.

The contour mining operation (Mine #3) principally studied was located in Logan County in southwestern West Virginia (Figure 23). The total disturbed area was 8.0 hectares (19.8 acres). The major soil association present was the same (Muskingum) as that present at Mines #1 and #2, with similar depth, drainage, and parent derivation. The Lower Kittanning coal seam was mined, with 30 m (100 ft) of overburden removed. The overburden was drilled, blasted, excavated, loaded with front-end loaders onto trucks, and hauled 274 m (900 ft) to a valley fill or 0.8 km (0.5 miles) to recontour sites. Coal was similarly loaded, but was hauled 6.4 km (4 miles) to a preparation plant. Regrading was accomplished by bulldozer and reclaimed land was revegetated by airplane and hydroseeder.

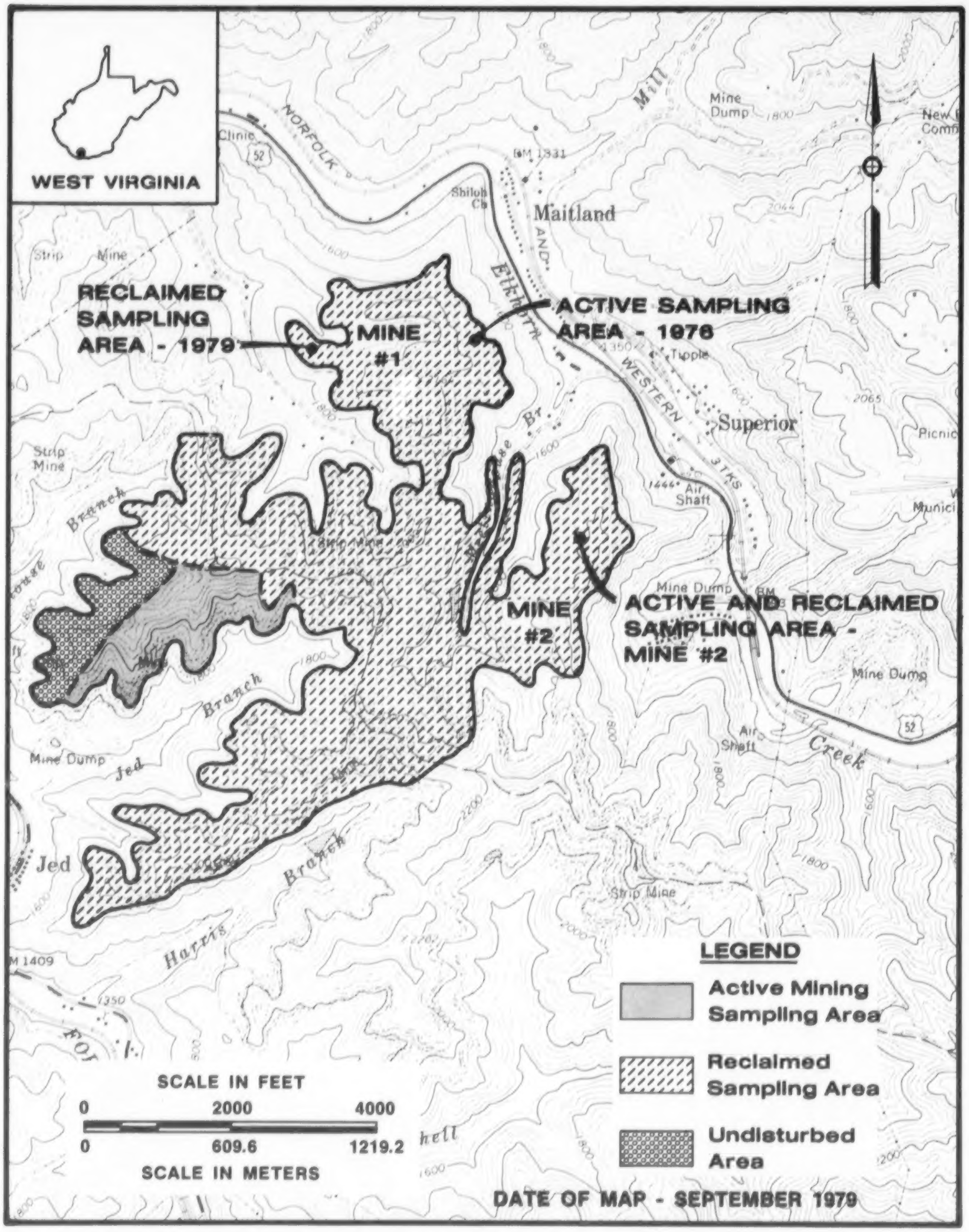

WEST VIRGINIA
RECLAIMED SAMPLING AREA - 1979
MINE #1
ACTIVE SAMPLING AREA - 1976
MINE #2
ACTIVE AND RECLAIMED SAMPLING AREA - MINE #2
LEGEND
Active Mining Sampling Area
Reclaimed Sampling Area
Undisturbed Area
SCALE IN FEET
0
2000
4000
0
609.6
1219.2
SCALE IN METERS
DATE OF MAP - SEPTEMBER 1979
Maitland
Superior
Jed
Elkhorn
NORFOLK AND WESTERN
3 TKS
Creek
Mill
Jed Branch
Harris Branch
Shiloh Ch
Clinic
52
BM 1331
Tipple
Air Shaft
Mine Dump
Strip Mine
Picnic
Munici
New Comm

Figure 22. Location map - mines #1 and #2.

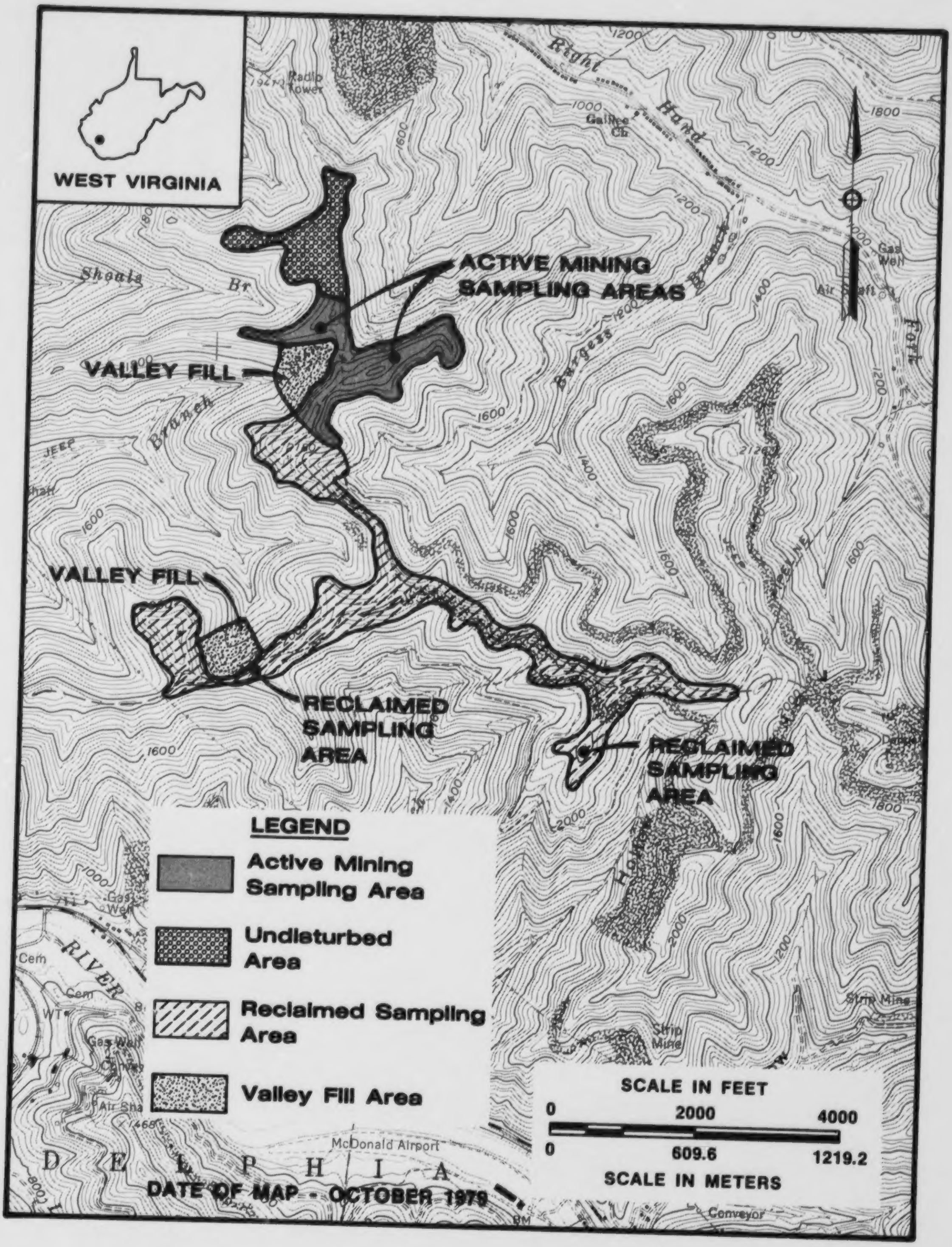

WEST VIRGINIA
ACTIVE MINING
SAMPLING AREAS
VALLEY FILL
VALLEY FILL
RECLAIMED
SAMPLING
AREA
RECLAIMED
SAMPLING
AREA
LEGEND
Active Mining Sampling Area
Undisturbed Area
Reclaimed Sampling Area
Valley Fill Area
SCALE IN FEET
0
2000
4000
0
609.6
1219.2
SCALE IN METERS
DATE OF MAP - OCTOBER 1979
Shoals Br
Branch
Right Hand
Burgess Branch
Fork
RIVER
McDonald Airport
Radio Tower
Gas Well
Air Shaft
Strip Mine
Conveyor

Figure 23. Location map - mine #3.

The mine employed a total of 22 people working two 10-hour shifts per day, 5 days per week. Average daily coal production was 698 metric (769 short) tons.

Additional fugitive dust samples were collected at another contour mining operation (Mine #4) located in Perry County in eastern Kentucky. The total disturbed area was 20.2 hectares (50 acres). The major soil association present was the Jefferson-Shelocta-Steinsberg, deep, well-drained, and derived from acidic sandstone and shale. The Hazard #5A coal seam was mined, with 14 m (46 ft) of overburden removed. The overburden was drilled, blasted, excavated, loaded with front-end loaders onto trucks, and hauled to recontour sites. Coal was similarly loaded and hauled 16 km (10 miles) to a preparation plant. Regrading was accomplished by bulldozer and reclaimed land was revegetated by hydroseeder. The mine employed a total of 80 people working two 10-hour shifts per day, 5 days per week. Average daily coal production was 1038 metric (1154 short) tons.

SAMPLING METHODS AND RATIONALE

Field Sample and Environmental Data Acquisition

Standard shelter high volume filtration samplers, BGI 1-A, were used for measurement of fugitive dust emissions. The samplers collected fugitive dust on 20.3 x 24.4 cm (8 x 10 in) binderless fiberglass filters. Electrical power for the samplers was provided by portable Kohler 1500 electric generators.

Fugitive dust emissions were sampled at Mines #1, #2, and #3 in July 1977 and November 1979, September 1977 and November 1979, and September 1979, respectively. On each date, three high volume samplers were operated simultaneously for sample periods ranging from 0.5 hours in extremely dusty situations to 2.0 hours where little dust was observed. Field personnel attended the samplers during all sample periods to adjust exposure time of individual filters, preventing overload with collected dust.

Originally, it was planned to monitor fugitive dust emissions of each of the following unit operations on an individual basis: drilling, blasting, overburden removal, coal loading, truck haulage of overburden and coal, and regrading. However, on the mine site it was evident that it would be impossible to separately monitor emissions from drilling, overburden removal, or coal loading. On a daily basis, the visually estimated area of active mining was small, 1.0-6.3 hectares (2.5-15.6 acres), and the heavy equipment performing the various functions operated in such close proximity to each other that individual dust plumes could not be discriminated. Furthermore, it was judged unsafe for personnel and sampling equipment to approach activity sufficiently close to attempt to observe individual plumes. Consequently, drilling, overburden removal, and coal loading were considered one joint dust emitting operation at each mine. Regrading of land where coal had been removed and truck haulage of overburden and coal on unpaved roads were sampled individually for dust emissions. Although monitoring of dust emission during blasting was anticipated, mine safety regulations and concern for safety of equipment prevented collection of such samples.

The planned rationale for location of individual samplers around dust producing activity was the collection of upwind and downwind samples of dust, allowing differentiation between ambient air and mining operation contributed dust concentrations. However, physical conditions of the mine site, particularly the presence of highwalls very close to mining activity and frequently fluctuating wind direction, resulted in modification of the sampling plan. It was decided to place the samplers as close as possible to the mining activity being monitored without interference with heavy equipment operation. Within the constraints of the terrain, the samplers were located around the mining activity as far apart as possible to ensure that changes in wind direction would still allow one sampler to be nearly directly downwind of the mining.

Samplers were moved frequently to allow collection of samples over a wide range of positions relative to wind and physical terrain, but always remained fixed during exposure of individual filters. Sampler distance to dust producing activity varied from 6 m (20 ft) to 91 m (300 ft).

Fugitive dust was monitored on revegetated reclaimed land to assess its potential as a dust emission source. Reclaimed areas were selected for monitoring based on revegetation of at least one year, isolation from active mining operations including haul roads of at least 0.8 km (0.5 miles), and degree of accessibility. Samplers were positioned in a triangular pattern at least 30 m (100 ft) apart and operated simultaneously.

The high volume samplers were calibrated in the laboratory and operated in the field according to manufacturer and EPA procedures and specifications. Individual filters were numbered prior to exposure and were placed in zip-lock plastic bags for transportation to the laboratory after exposure. Each exposed filter was accompanied by a data sheet containing the following information:

1) filter number
2) sampler number
3) mine designation
4) date
5) mining activity monitored
6) location of sampler relative to mining activity
7) initial and final flow rates
8) duration of exposure period
9) initial and final wind speed and direction
10) initial and final temperature
11) initial and final relative humidity

Temperature and relative humidity were measured with a field thermometer and hygrometer, respectively. Wind speed was determined with hand-held wind indicators. Wind direction and position of samplers relative to mining activities were determined with a compass.

In conjunction with high volume sampling, dustfall buckets were used at Mines #1 and #2 to measure settleable fugitive dust. Dustfall buckets were also used at Mine #4 in a limited fugitive dust emission study program without high volume sampling. The dustfall buckets employed were 18.7 cms (7.4 in) in diameter and supported by holders that elevated them 2.4 m (8 ft) above the surface. The dustfall buckets were placed at various distances from mining activity with sample periods of 24 hour duration. Distilled water was used as the collecting medium within the dustfall buckets.

Laboratory Procedures

Prior to exposure in the field, the high volume filters were weighed to 0.01 mg in the laboratory with a Mettler Balance, Model H54AR. Weight determination followed drying in an oven at 105°C (221°F) for 1 hour and 24 hours acclimation to room temperature in a dessicator. All weight determinations followed this procedure. Upon receipt of exposed filters in the laboratory, each was visually inspected for trapped insects. All trapped insects were carefully removed from the exposed filters before weight determination. The weight of collected fugitive dust was the difference between filter weights before and after exposure in the field. All filter numbers and weights were recorded in laboratory logs.

Dustfall bucket samples (distilled water plus settled material) were received in the laboratory and poured through a U.S. standard no. 20 sieve (opening = 0.85 mm, 0.033 in) to remove such extraneous materials as leaves and insects. The samples then were vacuum filtered through preweighed filter paper. Following filtration, the samples (filter paper plus settled dust) were dried and weighed. The weight of settled dust was the difference between filter weights before and after filtration. All sample numbers and weights were recorded in laboratory logs.

Data Preparation and Analysis

For each exposed high volume sampler filter, the quantity of collected fugitive dust (expressed in micrograms) divided by the total volume of air circulated through the high volume sampler (expressed in cubic meters) provided the density of fugitive dust present in the sampled air (expressed in micrograms per cubic meter) under the particular field conditions of temperature and atmospheric pressure encountered during the sampling period. However, for ease of comparison, all densities were standardized to densities at 25°C (298°K) and 760 mm Hg atmospheric pressure as suggested by Smith et al (1978).

It was anticipated that one high volume sampler would be upwind of mining activity each sample period, providing an estimate of the density of fugitive dust in ambient air. Unfortunately, this was not the case, due to frequently fluctuating wind direction and physical features of mine site terrain. Therefore, each density measurement was treated as a measurement of the fugitive dust present in ambient air plus fugitive dust emitted by the particular mining activity monitored. No subtraction of the ambient air fugitive dust component was attempted in data analysis. Implicit in this action was the belief that fugitive dust densities in ambient air were insignificant relative to mining emissions, particularly in light of the isolation of the mining operations in wooded mountainous areas far from other dust producing industrial activity.

Fugitive dust emission rates were calculated for drilling, overburden removal, and coal loading and for regrading at each mine, using the method for area sources employed in Appendix B, Cowherd et al (1974). The theoretical mathematical basis for this method is described on pages 39-40, Turner (1970). Emission factors were prepared for these operations using the calculated emission rates. Figure 24 is an example of the method used for emission rate calculation.

Fugitive dust emission rates were calculated for haul roads using the line source (Gaussian) dispersion equation employed in Axetell (1978). Emission factors were prepared for haul roads using the calculated emission rates. Estimated emission factors were calculated using an equation (Mann and Cowherd 1975) incorporating silt content of the road surface, mean vehicular speed, and selected area precipitation data. Examples of these calculations are provided in Figures 25 and 26.

The mass of dust (grams) collected in each dustfall bucket was divided by the dustfall bucket surface area (0.0275 m2) to yield a mass per unit area (grams per square meter). This expression represented an estimate of the dustfall at the sampler location for the particular 24 hour sample period. Since the samplers remained fixed in position during the entire study, sampler means as well as daily means of dustfall were calculated. This allowed observation of spatial as well as temporal variation in dustfall.

RESULTS AND DISCUSSION

Meteorological Conditions

Mean daily temperature, wind speed, and relative humidity measured on the mine sites during the study are listed in Table 30. Since the field study was conducted during several seasons, fugitive dust emissions were measured over a wide range of mean daily temperatures, 7-28°C (45-82°F). Mean daily wind speed generally was less than 6.0 m/sec (19.7 ft/ sec) with a maximum of 13.6 m/sec (44.6 ft/sec) recorded. Mean daily relative humidity was high with a minimum of 50% measured. No fugitive dust samples were collected less than 24 hours following precipitation.

The comprehensive equation:

$$Q = R\ C\ \mu\ \sigma_y\ \sigma_z$$

Where: Q = dust emission source strength (grams/sec)

R = ratio calculated 1 hour concentration to 3 minute concentration, derived from Table 5-1, Turner (1970)

C = dust concentration (grams/cubic meter)

μ = wind speed (meters/second)

σ_y = horizontal dispersion coefficient (meters)

σ_z = vertical disperson coefficient (meters)

To obtain σ_y and σ_z:

a. Calculate $\sigma_{yo} = S/4.3$

Where: S = length of a side of the area source (meters)

b. Obtain X_{yo} from Figure 3-2, Turner (1970), using σ_{yo} and the appropriate atmospheric stability class from Table 3-1, Turner (1970)

c. Calculate $X_1 = X + X_{yo}$

Where: X = distance of the sampler from the source (meters)

d. Obtain σ_y and σ_z from Figures 3-2 and 3-3, Turner (1970), using the appropriate atmospheric stability class.

Particular sample values and computation:

Horizontal and vertical dispersion coefficients

Figure 24. Sample calculation of fugitive dust emission rates - sources - drilling, overburden removal, coal loading and regrading.

a. σ_{yo} = S/4.3

= 250 m/4.3

= 58.1 m

b. X_{yo} = 0.34 km (stability class = B)

= 340.0 m

c. X_1 = $X + X_{yo}$

= 38.0 m + 340.0 m

= 378.0 m

d. σ_y = 64 m

σ_z = 38 m

The comprehensive equation:

$$Q = R\,C\,\mu\,\sigma_y\,\sigma_z$$

Where: R = 1.0/0.61

C = 0.0006342 g/m^3

μ = 2.9 m/sec

σ_y = 64 m

σ_z = 38 m

Q = 7.3 g/sec

To calculate an emission factor (EF), multiply the emission rate by appropriate factors:

EF = (7.3 g/sec)(3600 sec/hr)(18 hr/workday)(0.001 kg/g)
(10000 m^2/hectare)/(62500 m^2)

EF = 75.7 kg/workday hectare

*Adapted from Appendix B, Cowherd et al (1974).

Figure 24. (continued)

The comprehensive equation:

$$Q = X \sin \phi \sqrt{2\pi}\ \sigma_z\ \mu/2$$

Where: Q = dust emission source strength (grams/second meter)

X = dust concentration (grams/cubic meter)

ϕ = angle between wind direction and road

π = 3.14

σ_z = vertical standard deviation of plume concentration (meters)

μ = mean wind speed (meters/second)

To obtain σ_z:

a. calculate initial X_o in equation

$$\sigma_z = a\ (X + X_o)^b$$

Where: a and b are obtained from page 31, Axetell (1978), using the appropriate atmospheric stability class from Table 3-1, Turner (1970)
$X = 0$
σ_z = field estimate of initial plume height (meters)

b. calculate $\sigma_z = a\ (X + X_o)^b$

Where: a + b are as above
X_o from calculation above
X = mean distance of samplers to haul road (meters)

Particular sample values and computation:

Calculation of σ_z

a. Calculation of initial X_o, stability class: B

Figure 25. Sample calculation of fugitive dust emission rates for haul roads.

$\sigma_z = a\ (X + X_o)^b$

Where: $\sigma = 3.0$ m
$a = 0.147$
$b = 0.932$
$x = 0$

$3\ \text{m} = (0.147)X_o^{0.932}$

$X_o = 25.4$ m

b. calculation of σ_z

$\sigma_z = a\ (X + X_o)^b$

Where: a + b are as above
$X = 22$ m
$X_o = 25.4$ m

$\sigma_z = 5.36$ m

The comprehensive equation:

$$Q = X \sin \phi \sqrt{2\pi}\ \sigma_z\ \mu/2$$

Where: $X = 0.015972\ \text{g/m}^3$

$\phi = 45°$

$\sigma_z = 5.36$ m

$\mu = 3.9$ m/sec

$Q = 0.2959$ g/sec m

To calculate an emission factor (EF), multiply the emission rate by appropriate factors:

EF = (0.2959 g/sec m)(0.001 kg/g)(1000 m/km)(3600 sec/hr)/(13 vehicles/hr)

EF = 81.9 kg/vehicle km

*Adapted from Axetell (1978).

Figure 25. (continued)

The comprehensive equation:

$$E = (0.81s)\left(\frac{S}{30}\right)\left(\frac{365-W}{365}\right)$$

Where: E = emission factor (pounds/vehicle mile)

s = silt content of road surface material (percent)

S = mean vehicle speed (miles/hour)

W = mean annual number of days with $\geq$ 0.254 millimeters (0.01 inches) of rainfall

s can be approximated by the silt content of the parent soil in the area (Cowherd _et al_ 1974).

Particular sample values and computation:

$$E = (0.81s)\left(\frac{S}{30}\right)\left(\frac{365-W}{365}\right)$$

Where: s = 12.25%

S = 28 miles/hour

W = 170 days

E = 4.9 lbs./vehicle mile

The volume must be adjusted through multiplication by a factor of 1.5, because the equation has been developed for use with four-wheeled vehicular traffic. Haul trucks have six wheels; hence, multiplication by 1.5.

E = (4.9 lbs./vehicle mile) (1.5)

E = 7.5 lbs./vehicle mile

*Adapted from Mann and Cowherd (1975).

Figure 26. Sample calculation of estimation of a fugitive dust emission factor from a haul road.

TABLE 30. MEAN DAILY TEMPERATURE, WIND SPEED, AND RELATIVE HUMIDITY MEASURED ON FUGITIVE DUST EMISSION SAMPLE DATES

Mine	Date	Mean temperature		Mean wind speed		Mean relative humidity %
		(°C)	(°F)	m/sec	ft/sec	
1	ACTIVE MINING					
	7/18/77	20	68	5.7	18.7	59
	7/19/77	21	70	3.1	10.2	64
	7/20/77	21	70	5.3	17.4	60
	7/26/77	19	66	1.6	5.2	54
	7/27/77	19	66	3.0	9.8	54
	RECLAIMED AREAS					
	11/15/79	7	45	3.6	11.8	74
	11/16/79	9	48	1.3	4.3	70
2	ACTIVE MINING					
	9/13/77	24	75	7.0	23.0	70
	9/14/77	22	72	0.7	2.3	69
	9/15/77	21	70	7.2	23.6	64
	9/19/77	22	72	4.5	14.8	72
	9/20/77	15	59	4.1	13.4	50
	9/21/77	15	59	5.9	19.4	76
	9/22/77	21	70	6.9	22.6	75
	9/23/77	16	61	3.1	10.2	71
	RECLAIMED AREAS					
	11/16/79	10	50	2.4	7.9	61
	11/17/79	10	50	2.5	8.2	68
3	ACTIVE MINING					
	9/11/79	28	82	1.2	3.9	58
	9/12/79	21	70	5.5	18.0	60
	9/13/79	26	79	13.6	44.6	59
	9/20/79	15	59	5.9	19.4	75
	RECLAIMED AREAS					
	9/17/79	23	73	1.9	6.2	74
	9/18/79	16	61	3.2	10.5	81
	9/19/79	23	73	4.7	15.4	78

Mining Equipment

Major equipment used at the mine sites is listed in Table 31. Although the same general types of equipment were used at all the mines, there was variation in number and manufacturer of individual pieces. In general, dozers and front-end loaders in combination with off-road trucks were used to remove overburden, rather than draglines or shovels. No trucks with capacity larger than 50 tons were used to haul coal or overburden.

TABLE 31. MAJOR EQUIPMENT EMPLOYED AT THE MONITORED MINES

Mine	Category	Capacity	Number
1 and 2	Road Graders		
	Cat 14		1
	Pan Scrapers		
	Cat 651		2
	Euclid T524		2
	Drills		
	Drill Tech		1
	Robbins		1
	Dozers		
	Cat. D-8		1
	Cat. D-9		5
	International TD-25		1
	Fiat-Allis HD-41		1
	Front-End Loaders		
	Cat. 988		2
	Cat. 992		2
	Trucks (On-Road)		
	Kenworth	22-25 Tons	4
	Trucks (Off-Road)		
	Euclid R-50	50 Tons	4
3	Road Graders		
	Cat. 14		1
	Drills		
	Robbins		1
	Dozers		
	Cat. D-7		1
	Cat. D-9		2
	Front-End Loaders		
	Cat. 988		1
	Cat. 992		1
	Trucks (Off-Road)		
	Euclid R-50		4
	Kline		2

(continued)

TABLE 31. (continued)

Mine	Category	Capacity	Number
4	Road Graders		
	Cat. 12F		1
	Cat. 14D		1
	Pan Scrapers		
	Cat. 641		2
	Drills		
	Chicago Pneumatic		2
	Ingersol Rand		1
	Dozers		
	Cat. D-7		1
	Cat. D-8		2
	Cat. D-9		5
	Front-End Loaders		
	Cat. 988		1
	Cat. 992		4
	Trucks (On-Road)		
	Mack	22 Tons	11
	Trucks (Off-Road)		
	Cat. 769	50 Tons	1
	Cat. 773	50 Tons	2
	Euclid R-50	50 Tons	2
	International 350	50 Tons	2

Fugitive Dust

Data for individual high volume samples of fugitive dust (suspended particulates) are presented in Appendix H. Descriptive statistics of the high volume sampler data are presented in Table 32. Mean densities are graphically displayed in Figure 27.

Totals of 94 and 51 samples were collected in monitoring fugitive dust emissions from active mining unit operations and in reclaimed areas, respectively. More samples of emissions from drilling, overburden removal, and coal loading were collected (60) than from regrading (22) or haul roads (12) because of the apparently greater concentration of dust producing activity in a small area in the former category. Nearly equal numbers of samples of emissions from active mining unit operations were collected on the mines employing mountaintop removal - Mines #1 and #2 (46) and contour stripping - Mine #3 (48).

The high values of standard deviation relative to the sample means indicate considerable spatial and temporal variation among individual samples as estimates of fugitive dust density (concentration). There was great variation in mean densities among mines within the same active mining unit operation. In general, the greatest densities of fugitive dust in unit operations were measured at Mine #2, with Mine #3

TABLE 32. DESCRIPTIVE STATISTICS OF SUSPENDED PARTICULATE HIGH-VOLUME SAMPLER DATA

Operation	Mine	Number of samples	Mean wind speed (m/sec)	Mean wind speed (ft/sec)	Mean distance source to receptor (m)	Mean distance source to receptor (ft)	Suspended particulate concentration ($\mu g/m^3$) Mean	Suspended particulate concentration ($\mu g/m^3$) Standard deviation
Drilling	1	13	2.9	9.5	38	125	634.2	398.3
Overburden Removal	2	14	4.3	14.1	30	100	13882.3	9751.6
Coal Loading	3	33	3.6	11.8	25	83	2112.1	1671.8
Regrading	1	5	3.8	12.5	49	160	690.7	423.2
	2	10	3.3	10.9	32	105	5976.4	4152.7
	3	7	3.1	10.2	35	115	2822.6	2199.9
Haul Roads	2	4	3.9	12.8	22	72	15972.0	11881.5
	3	8	6.6	21.7	6	20	11150.6	8635.2
Reclaimed Areas	1	17	2.8	9.2	543*	1786*	184.4	124.0
	2	18	2.5	8.2	535*	1760*	221.3	184.6
	3	16	2.0	6.6	1371*	4510*	233.3	135.5

*Mean distance to nearest working area.

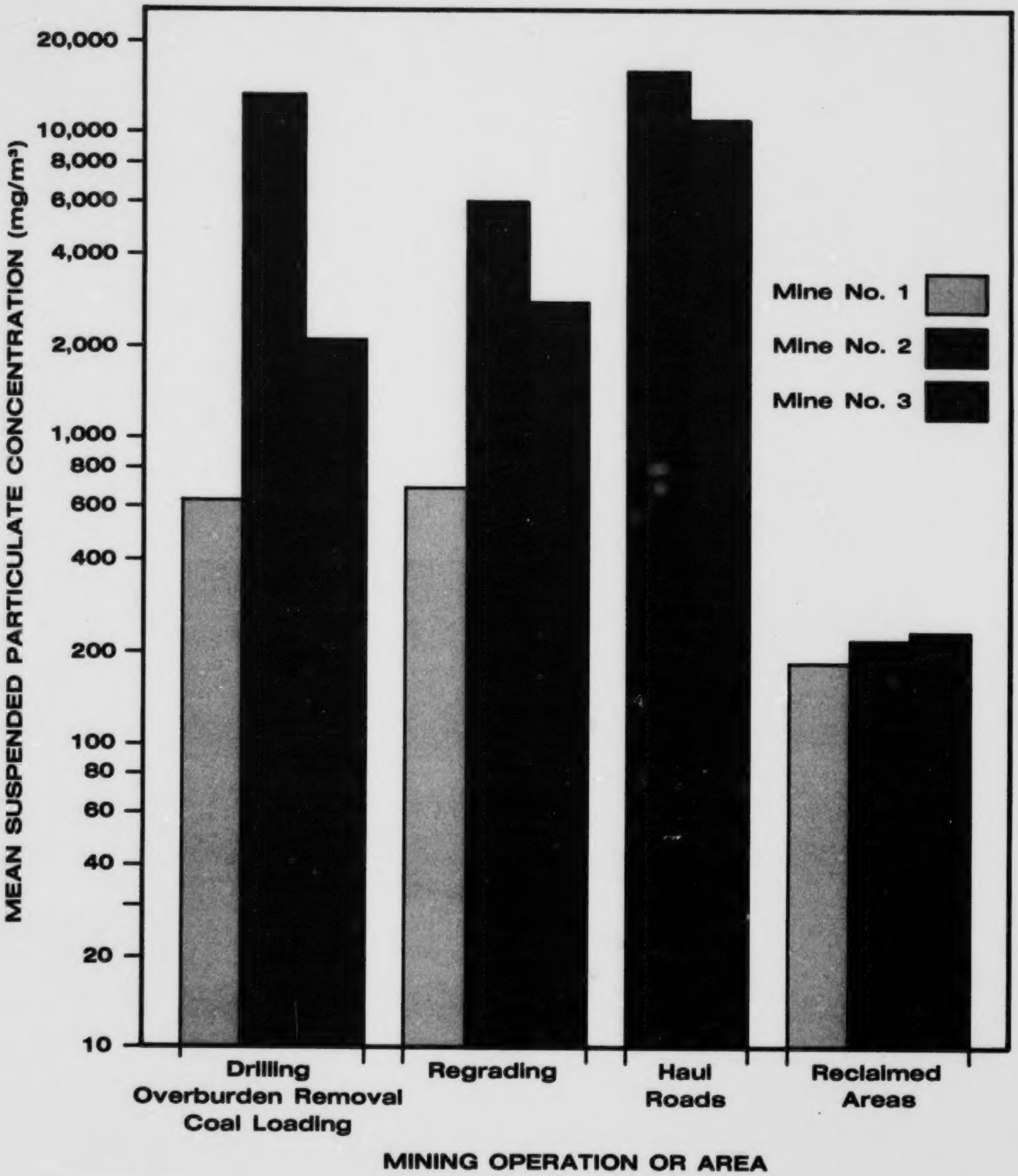


Figure 27. Suspended particulate concentration.

intermediate. It is interesting to note the great disparity in recorded densities between Mines #1 and #2, in light of the fact that both were geographically very close and shared similar overburden composition.

Of all the unit operations monitored, haul road traffic produced the greatest density of fugitive dust, 15972.0 g/m^3 at Mine #2 and 11150.6 g/m^3 at Mine #3. Haul road traffic was not monitored at Mine #1. Drilling, overburden removal, and coal loading was nearly as dust-producing (13882.3 g/m^3) as haul road traffic at Mine #2. Regrading was much less dust producing (5976.4 g/m^3) relative to the other active mining operations at this mine. In contrast, emissions from regrading (2822.6 g/m^3) and drilling, overburden removal, and coal loading (2112.1 g/m^3) were nearly equal, but much less than from haul road traffic at Mine #3. Regrading (690.6 g/m^3) and drilling, overburden removal, and coal loading (634.2 g/m^3) were also nearly the same in dust emission at Mine #1.

Fugitive dust density measured on reclaimed areas was nearly the same at all three mines: Mine #1 - 184.4 g/m , Mine #2 - 221.3 g/m^3, and Mine #3 - 233.3 g/m^3. These values may be loosely interpreted as approximations of ambient air dust density at the mines. However, it must be noted that the samples were collected on areas vegetated only by grasses, weeds, and occasional shrubs. Therefore, the soil was not heavily rooted or covered with leaf litter and may be expected to contribute more dust through wind erosion than the surrounding forest.

Emission rates and factors calculated for drilling, overburden removal, and coal loading and for regrading at the three mines are presented in Table 33. Emission factors are graphically displayed in Figure 28. Emission rates were defined in terms of grams per second (pounds per second) and kilograms per workday (pounds per workday). A workday was defined as the number of hours per day during which mining activity took place (10 hours at mines #1 and #2, 20 hours at mine #3). Calculation of dust emission rate on a per workday basis allowed determination of the quantity of dust produced as a result of one day's mining activity. Emission factors were defined in terms of kilograms per workday per hectare (pounds per workday per acre) which allowed determination of dust emission on a unit disturbed area basis.

Emission rates and factors were highest at Mine #2, with Mine #3 intermediate. Of the two unit operations, drilling - overburden removal - coal loading displayed the higher dust emission rates at Mine #2, 131.6 g/sec (0.290 lb/sec) or 8527.7 kg/workday (18792.0 lb/workday). However, emission rates for regrading were higher than for the other operation at Mine #1, 10.3 g/sec (0.023 lb/sec) or 667.4 kg/workday (1490.4 lb/workday), and at Mine #3, 6.9 g/sec (0.015 lb/sec) or 496.8 kg/workday (1080.0 lb/ workday). Emission factors followed the pattern described for emission rates, higher for drilling, overburden removal, and coal loading at Mine #2, 2131.9 kg/workday hectare (1897.4 lb/workday acre), and for regrading at Mines #1 and #3, 106.8 kg/workday hectare (95.1 lb/workday acre) and 381.6 kg/workday hectare (339.6 lb/workday acre), respectively.

TABLE 33. FUGITIVE DUST EMISSION RATES AND FACTORS CALCULATED FOR DRILLING-OVERBURDEN REMOVAL-COAL LOADING AND FOR REGRADING

Operation	Mine *	Emission rates (g/sec)	Emission rates (lbs/sec)	Emission rates (kg/workday)	Emission rates (lb/workday)	Emission factors (kg/workday hectare)	Emission factors (lb/workday acre)
Drilling-Overburden Removal-Coal Loading	1	7.3	0.016	473.0	1036.8	75.7	67.4
	2	131.6	0.290	8527.7	18792.0	2131.9	1897.4
	3	5.3	0.012	381.6	864.0	381.6	339.6
Regrading	1	10.3	0.023	667.4	1490.4	106.8	95.1
	2	46.9	0.103	3039.1	6674.4	759.8	676.2
	3	6.9	0.015	496.8	1080.0	496.8	442.2

*Mines #1 and #2 utilize an 18 hour workday, Mine #3 utilizes a 20 hour workday.

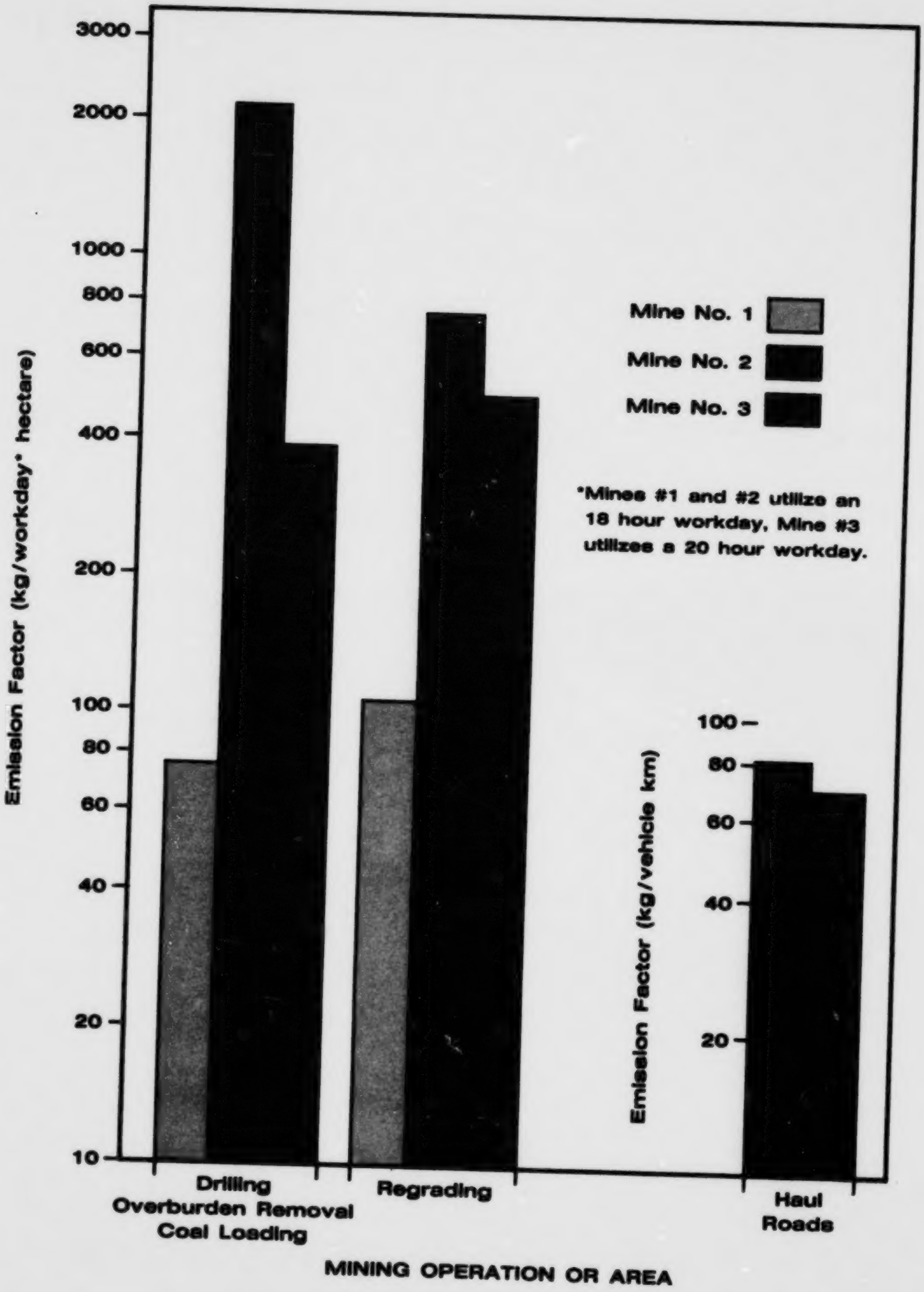


Figure 28. Emission factors.

Fugitive dust emission rates and factors calculated for haul road traffic at Mines #2 and #3 are presented in Table 34. Estimated values for these parameters prepared using the method outlined by Mann and Cowherd (1975) are also presented for comparison. Emission rates were slightly higher at Mine #2, 0.3 g/sec meter (1.0 lb/sec mile), than at Mine #3, 0.2 g/sec meter (0.8 lb/sec mile), reflecting the higher volume of traffic at the former mine. The emission factor, which incorporates traffic volume into its calculation, also was slightly higher at Mine #2, 81.9 kg/vehicle km (290.4 lb/vehicle mile), than at Mine #3, 69.6 kg/vehicle km (246.8 lb/ vehicle mile).

Calculated values based on field data differed greatly from estimated values. However, it should be noted that the estimated values were prepared using an equation that Mann and Cowherd (1975) recommended as valid for vehicle speeds in the range 48-80 km/hr (30-50 miles/hr). The mean speeds of vehicles on the haul roads monitored were 45 km/hr (28 miles/hr) at Mine #2 and 42 km/hr (26 miles/hr) at Mine #3, both slightly below the recommended range. The silt content of the dirt road surface, which Cowherd et al (1974) stated could be approximated by the silt content of the parent soil, entered the calculation as well. It is possible that the actual silt content of the road surface (not measured) may have deviated significantly from the parent soil approximation employed in the estimation. Furthermore, the equation probably was devised using data obtained in observation of automobile and pick-up truck traffic on rural roads and may not be applicable to 50 ton off-road truck traffic on haul roads.

Dust Fall

Data for individual dustfall samples collected at Mines #1, #2, and #4 are presented in Appendix H. Descriptive statistics of dustfall measurements are presented in Tables 35-37. The high values of standard deviation relative to sample means indicate considerable spatial and temporal variation among individual samples.

Among the three mines, Mine #1 displayed the greatest mean dustfall measured (1.47585 g/m2), with Mines #2 (1.13526 g/m2) and #4 (1.17091 g/m2) narrowly separated. The expected inverse relationship between mean dustfall and mean distance of source to receptor was not present because the buckets at Mine #4 were much closer to the dust emitting activity than those at the other mines.

At each mine, mean values calculated for each sampler location varied greatly. Furthermore, there was no inverse relationship between source to receptor distance and mean dust fall at any of the mines. The likely explanation is related to spatial arrangement of the dustfall buckets around dust emitting activity and 24 hr mean wind direction. A dustfall bucket that was a greater distance from the dust source, but more frequently downwind of it than another dustfall bucket closer to the source may record a larger dust fall.

TABLE 34. FUGITIVE DUST EMISSION RATES AND FACTORS CALCULATED FOR HAUL ROADS

Mine	Emission rates (g/sec m)	 (lb/sec mile)	Mean traffic volume (vehicles/hr)	Emission factors* (kg/vehicle km)	 (lb/vehicle mile)
2	0.3	1.0	13	81.9 (2.1)	290.4 (7.5)
3	0.2	0.8	11	69.6 (1.5)	246.8 (5.4)

*Estimated values in parentheses calculated using method outlined in Mann and Cowherd (1975).

TABLE 35. DESCRIPTIVE STATISTICS OF DUSTFALL DATA COLLECTED AT MINE #1

Sampler group		Distance: source to receptor (m)	Distance: source to receptor (ft)	No. of Samples	Total dustfall (g/m^2) Mean	Total dustfall (g/m^2) Standard deviation	Projected monthly accumulation* (g/m^2 month)
Location	A	249	820	5	0.39411	0.32126	11.8
	B	90	295	6	1.57382	0.71562	47.2
	C	179	590	7	1.35714	1.07779	40.7
	D	149	490	6	2.32939	1.64403	69.9
	E	274	900	6	1.97454	1.18414	59.2
	F	274	900	6	1.06558	1.05942	32.0
Day	1			6	1.73940	1.23709	52.2
	2			6	1.47273	1.07841	44.2
	3			6	1.91400	1.31452	57.4
	4			6	0.86976	0.83372	26.1
	5			6	1.54363	1.35074	46.3
	6			4	1.77273	1.61163	53.2
	7			2	0.40127	0.03934	12.0
			Total samples	36	1.47585	1.18274	44.3

*Mean value x 30 days

TABLE 36. DESCRIPTIVE STATISTICS OF DUSTFALL DATA COLLECTED AT MINE #2

Sampler group		Distance: source to receptor (m)	(ft)	No. of samples	Total dustfall (g/m^2) Mean	Standard deviation	Projected monthly accumulation* (g/m^2/month)
Location:	A	122	400	8	1.28377	1.13398	38.5
	B	182	600	8	1.02209	0.70700	30.7
	C	730	2400	7	0.93678	0.33200	28.1
	D	775	2550	8	0.51132	0.13629	15.3
	E	775	2550	8	1.62500	1.12440	48.8
	F	730	2400	8	1.40782	0.94878	42.2
Day:	1			6	0.97212	0.52694	29.2
	2			6	0.61364	0.20414	18.4
	3			6	1.10849	1.10694	33.3
	4			6	0.99994	0.31635	30.0
	5			6	0.98546	0.37510	29.6
	6			6	1.50127	1.32559	45.0
	7			6	1.98394	1.25718	59.5
	8			5	0.87367	0.61255	26.2
Total samples				47	1.13526	0.86759	34.1

*Mean value x 30 days.

TABLE 37. DESCRIPTIVE STATISTICS OF DUSTFALL DATA COLLECTED AT MINE #4

Sampler group		Distance: source to receptor (m)	Distance: source to receptor (ft)	No. of samples	Total dustfall (g/m^2) Mean	Total dustfall (g/m^2) Standard deviation	Projected monthly accumulation* (g/m^2 month)
Location	A	23	75	2	0.94546	1.23422	28.4
	B	23	75	2	0.70910	0.07714	21.3
	C	23	75	3	1.98788	1.61372	59.6
	D	23	75	3	0.81212	0.31771	24.4
Day	1			4	1.86364	1.30483	55.9
	2			3	0.56970	0.07570	17.1
	3			3	0.84848	0.84292	25.5
			Total samples	10	1.17091	1.04647	35.1

*Mean value × 30 days

Daily means calculated at each mine also varied considerably. This probably was a function of changing meteorological conditions and mining activity on a day-to-day basis.

The projected monthly accumulation of dustfall at Mines #1, #2 and #4, based on the sample data, were 44.3 g/m^2, 34.1 g/m^2, and 35.1 g/m^2, respectively.

Conclusions

The study of fugitive dust emissions by high volume sampling revealed large variation among individual samples, both spatially and temporally. Haul road traffic provided the greatest dust emission. At one mine, drilling, overburden removal, and coal loading monitored as a joint operation was nearly as dust producing as haul road traffic, with regrading a distant third. However, at two other mines, emissions from drilling, overburden removal, and coal loading and from regrading were similar, with those from regrading somewhat higher. Fugitive dust on reclaimed areas at all three mines was nearly identical and quite low relative to that measured near active mining operations.

Both mountaintop removal mines were greatly different in measured densities of fugitive dust emissions. The contour mine was intermediate and displayed measured densities similar to those observed at the less dust producing mountaintop removal mine. Therefore, it was not possible to ascertain conclusively which mining technique was the most dust producing.

The study of dustfall also revealed large spatial and temporal variation among individual samples. No inverse relationship between source-receptor distance and mass of dustfall was observed. There was no large difference in mass of dustfall between the mountaintop removal and contour mines.

It would appear that if similar machinery is used in both mining techniques, as it was at the mines monitored, differences in fugitive dust emissions are the result of local soil types and meteorological conditions, rather than the result of mining technique.

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APPENDIX A
STORM HYDROGRAPHS
INTENSIVE SITE KY-07-LA

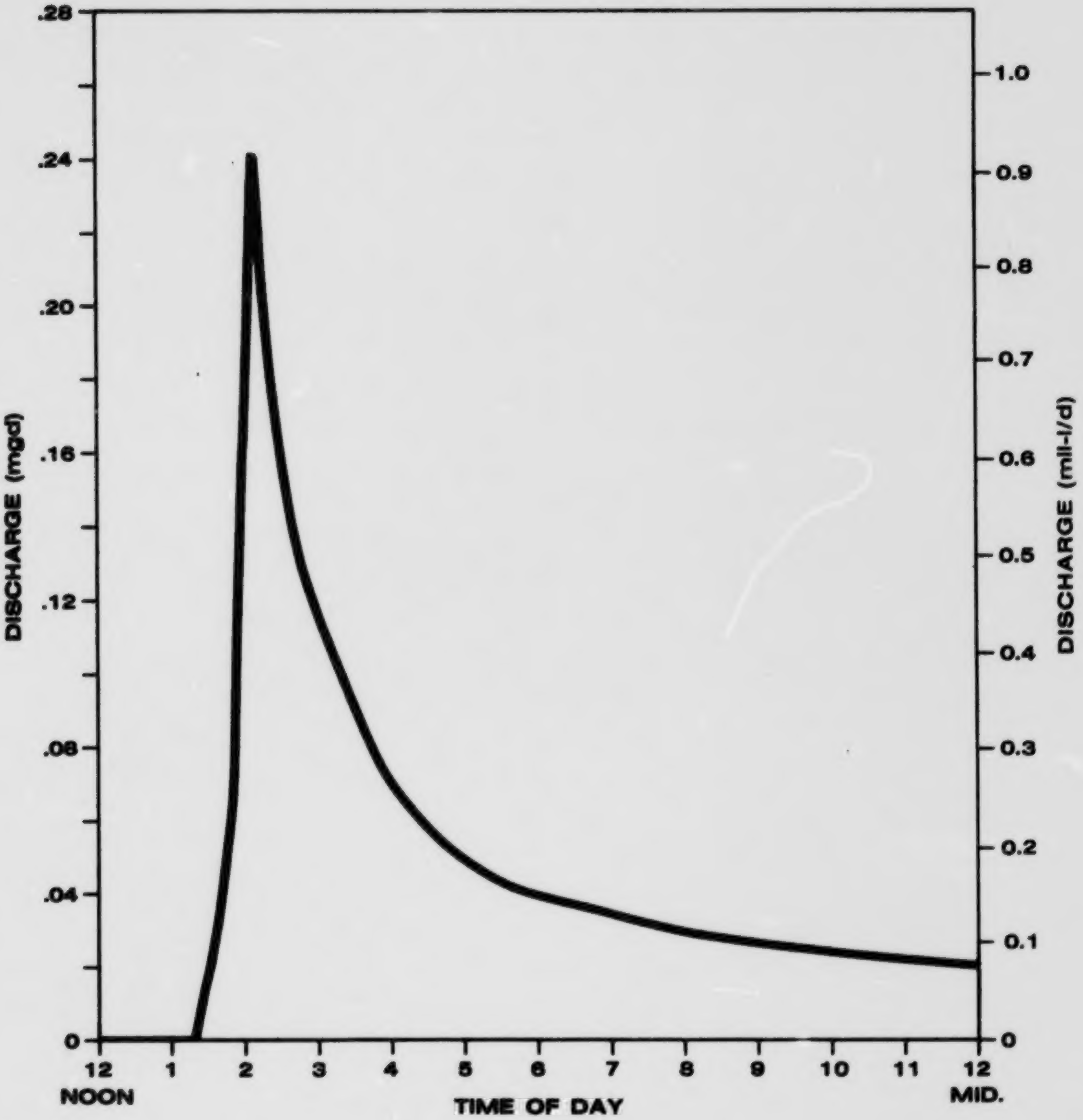


Figure A-1. Intensive site KY-07-LA runoff hydrograph - May 30, 1976.

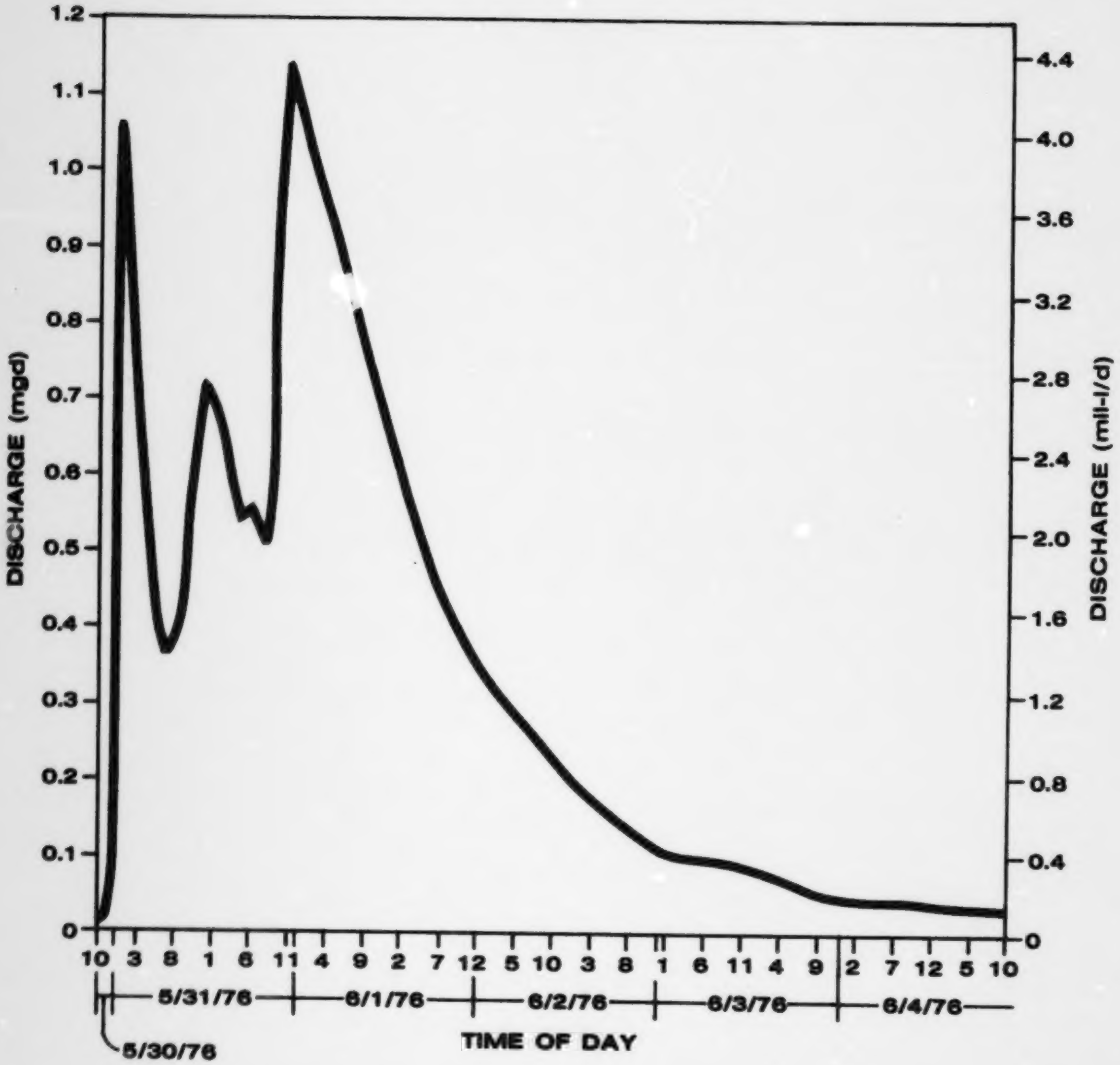


Figure A-2. Intensive site KY-07-LA runoff hydrograph - May 30 - June 4, 1976.

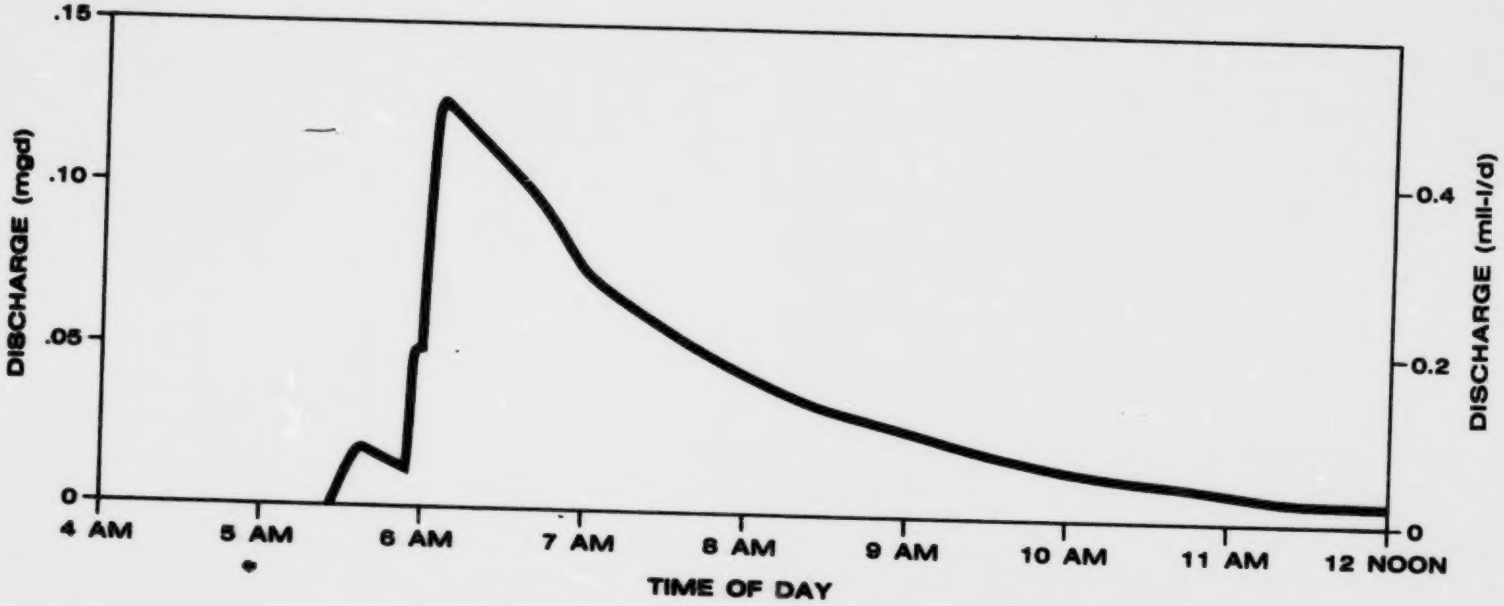


Figure A-3. Intensive site KY-07-LA runoff hydrograph - August 15, 1976.

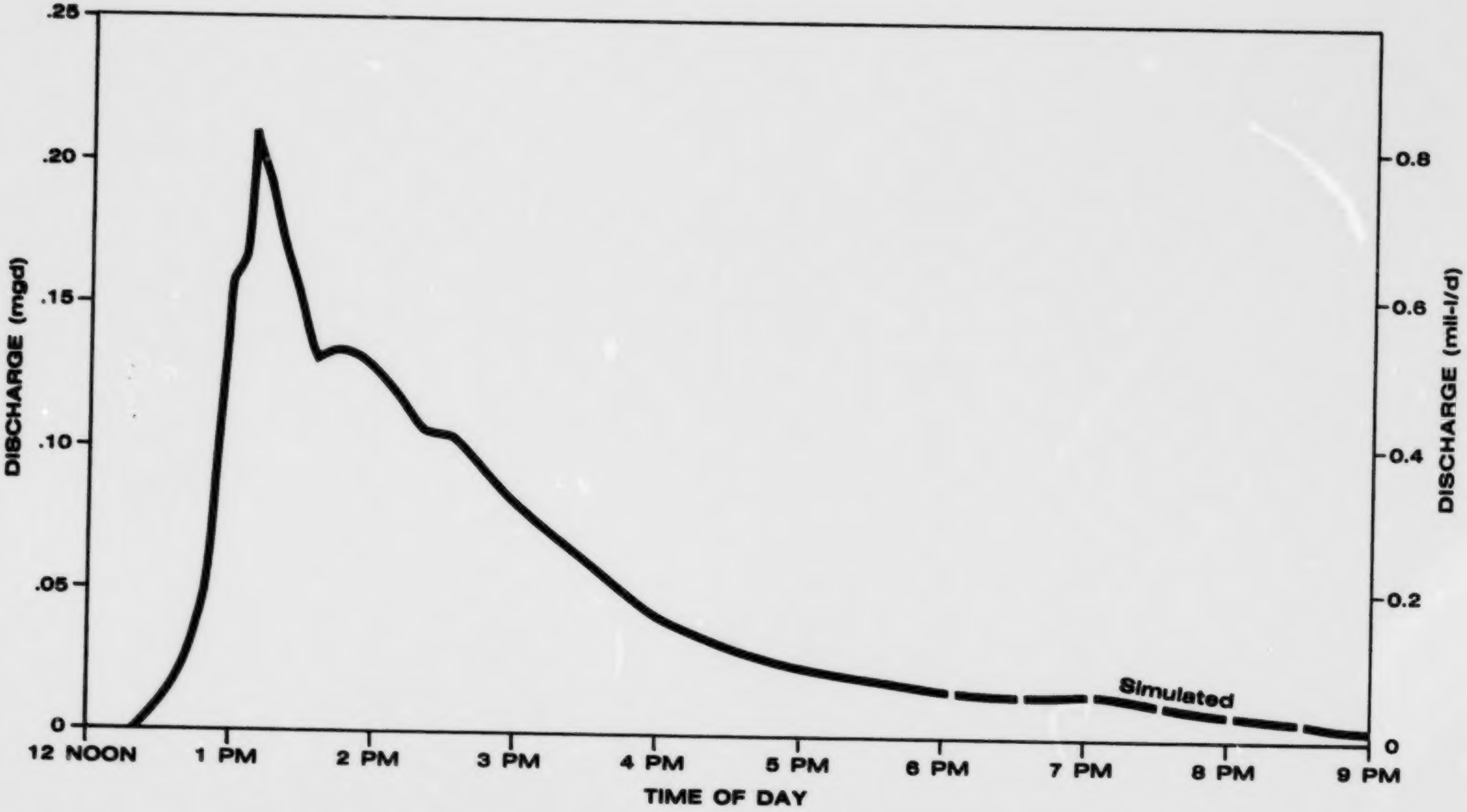


Figure A-4. Intensive site KY-07-LA runoff hydrograph - September 27, 1976.

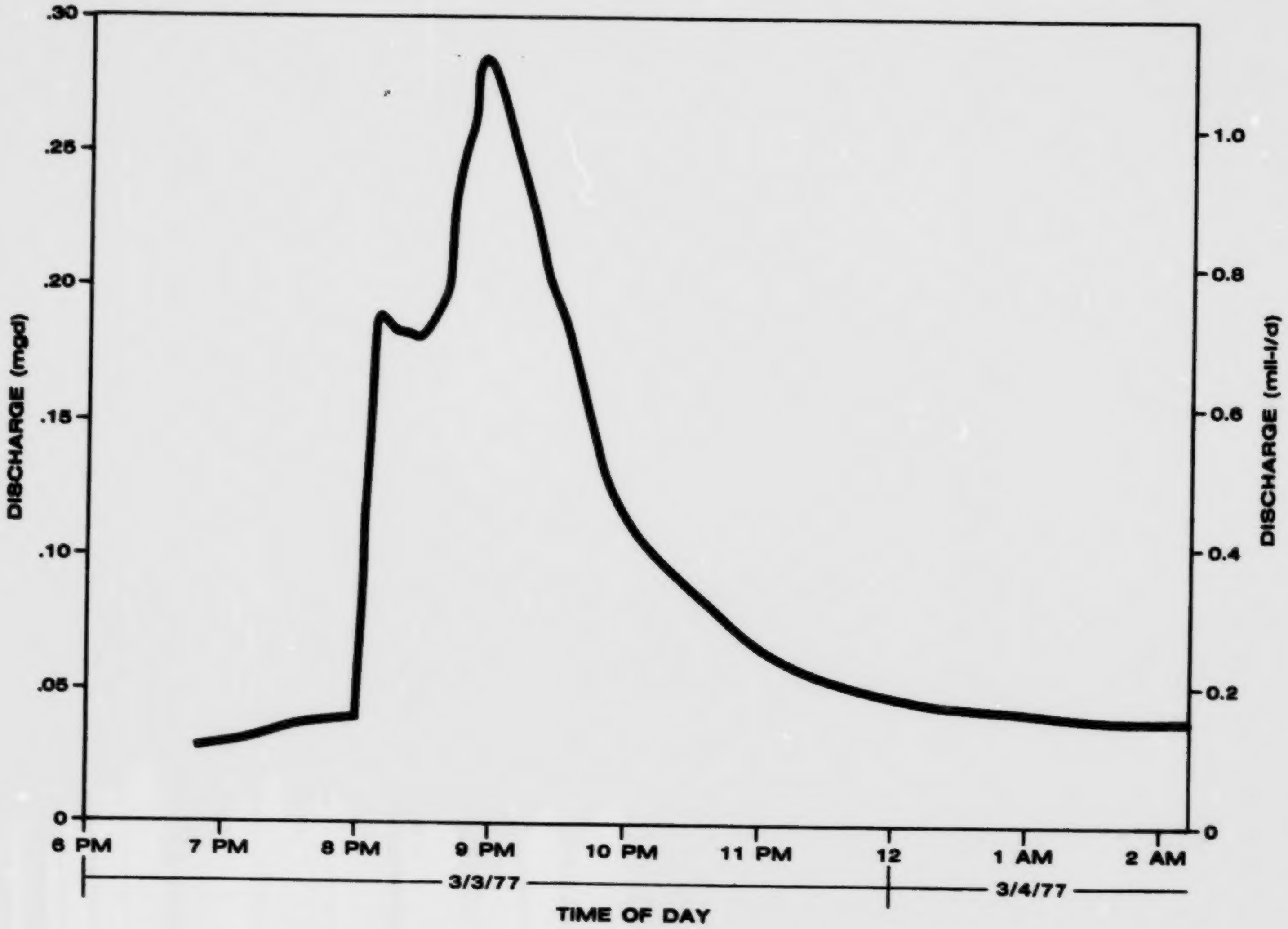


Figure A-5. Intensive site KY-07-LA runoff hydrograph - March 3-4, 1977.

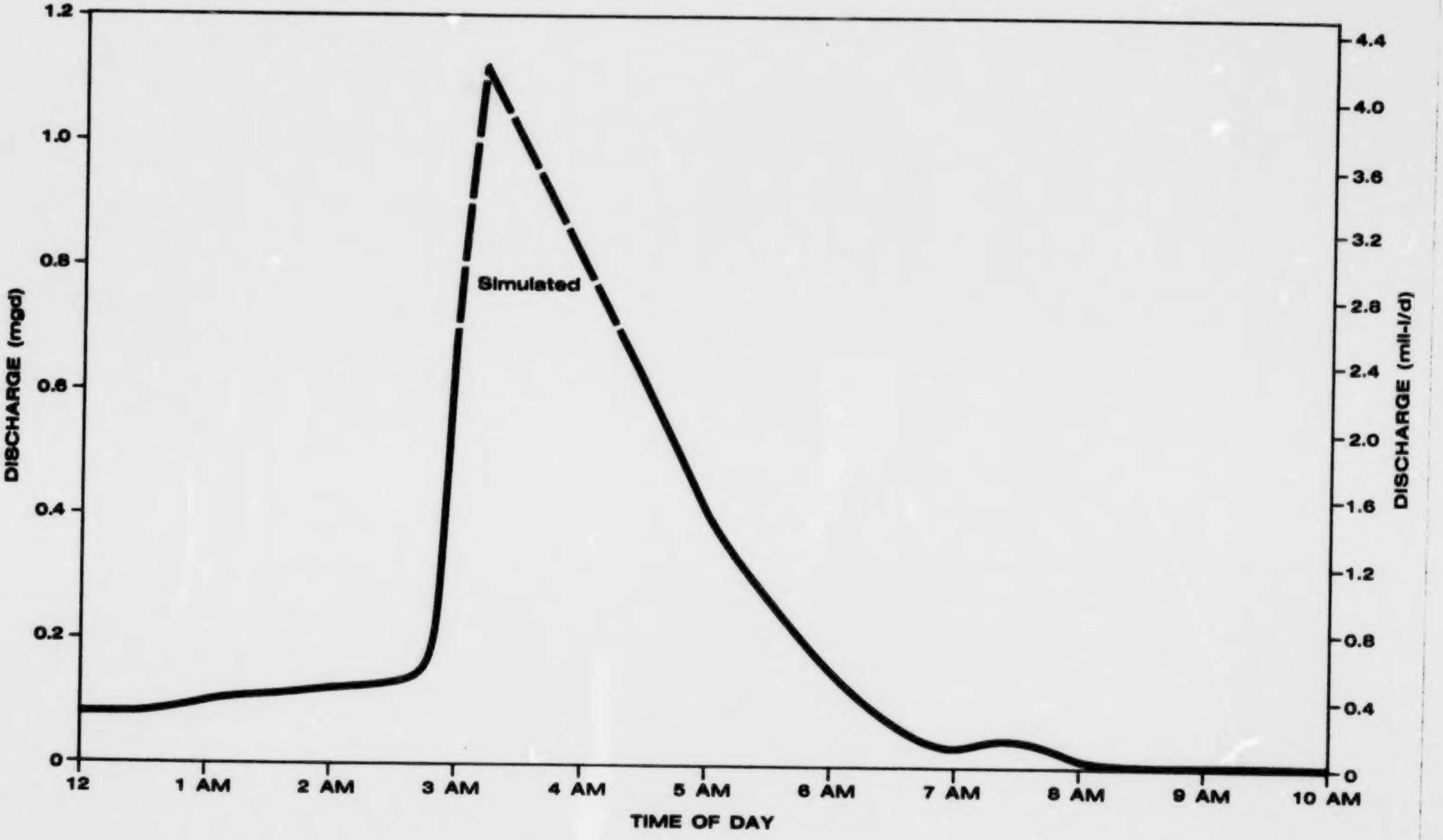


Figure A-6. Intensive site KY-07-LA runoff hydrograph - March 22, 1977.

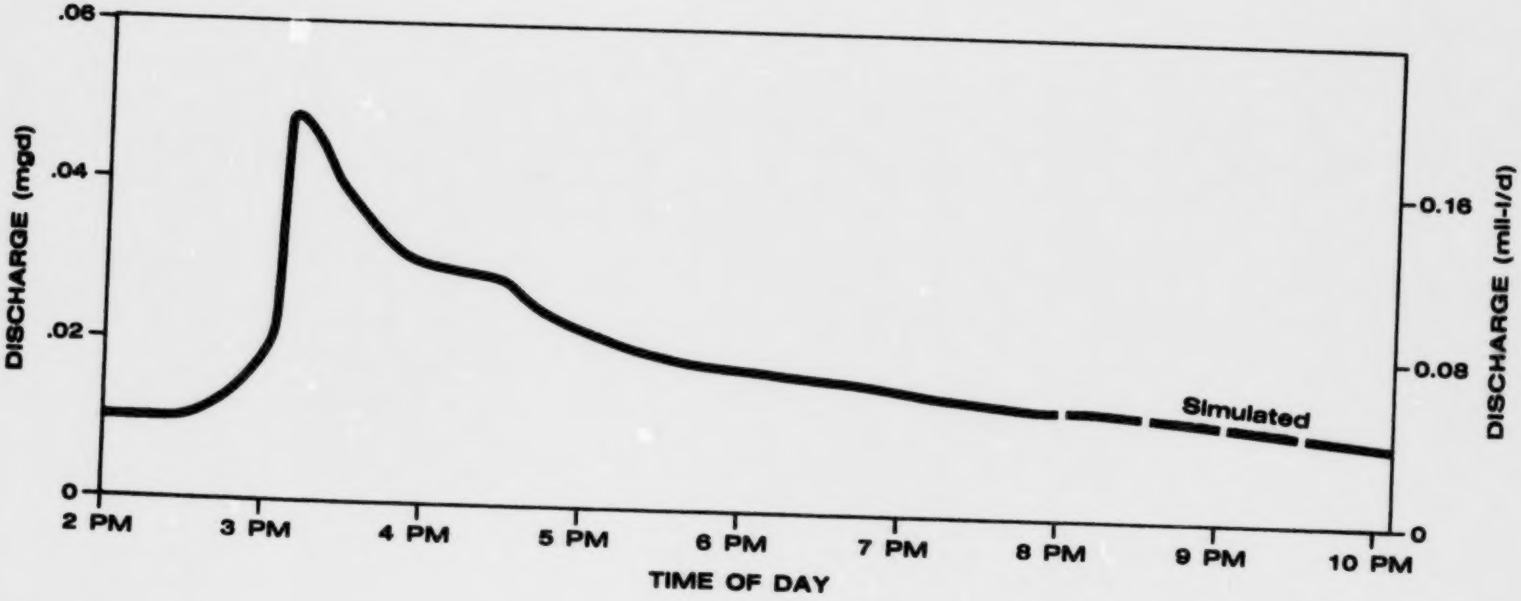


Figure A-7. Intensive site KY-07-LA runoff hydrograph - December 15, 1977.

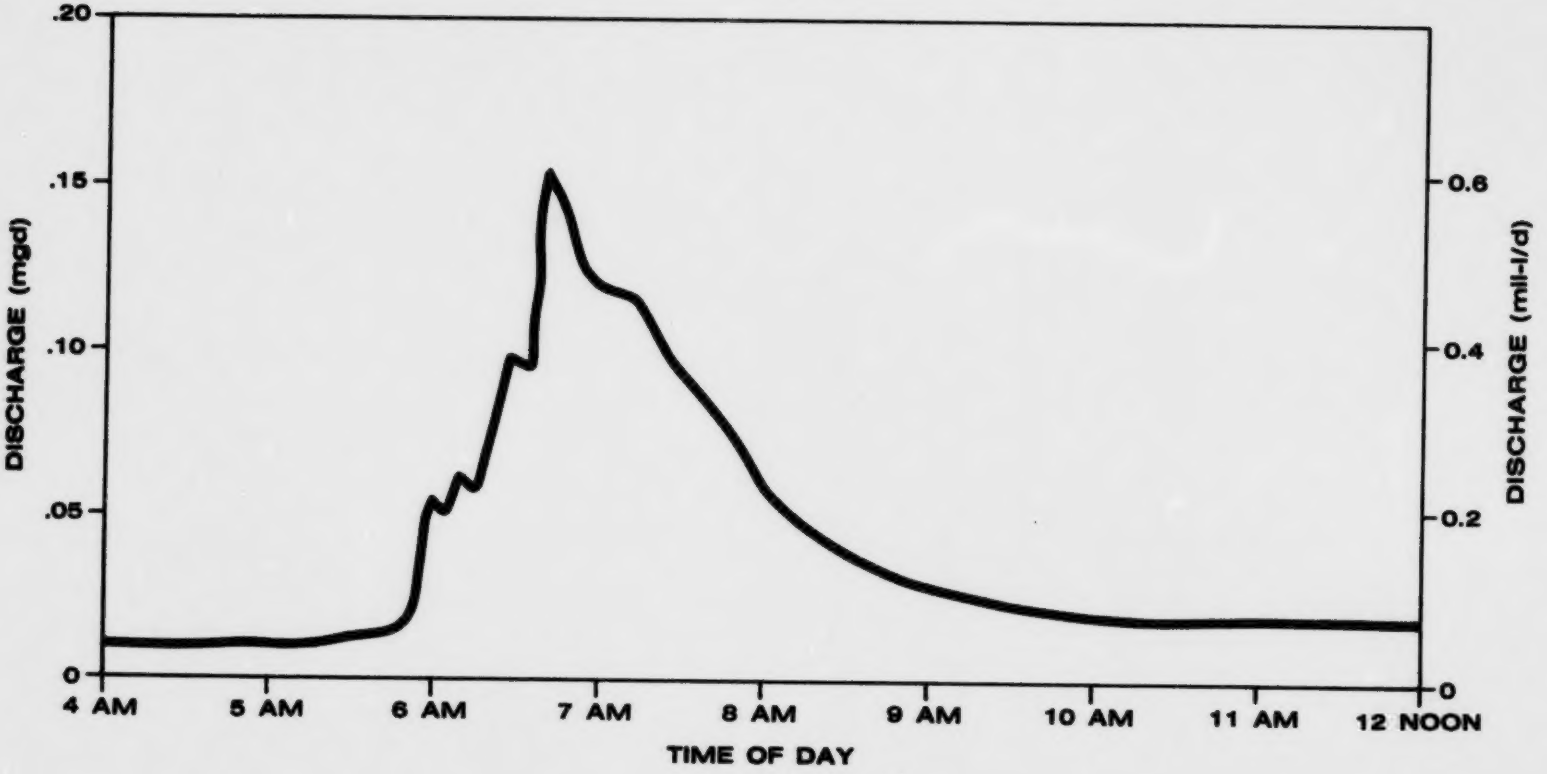


Figure A-8. Intensive site KY-07-LA runoff hydrograph - April 24-25, 1978.

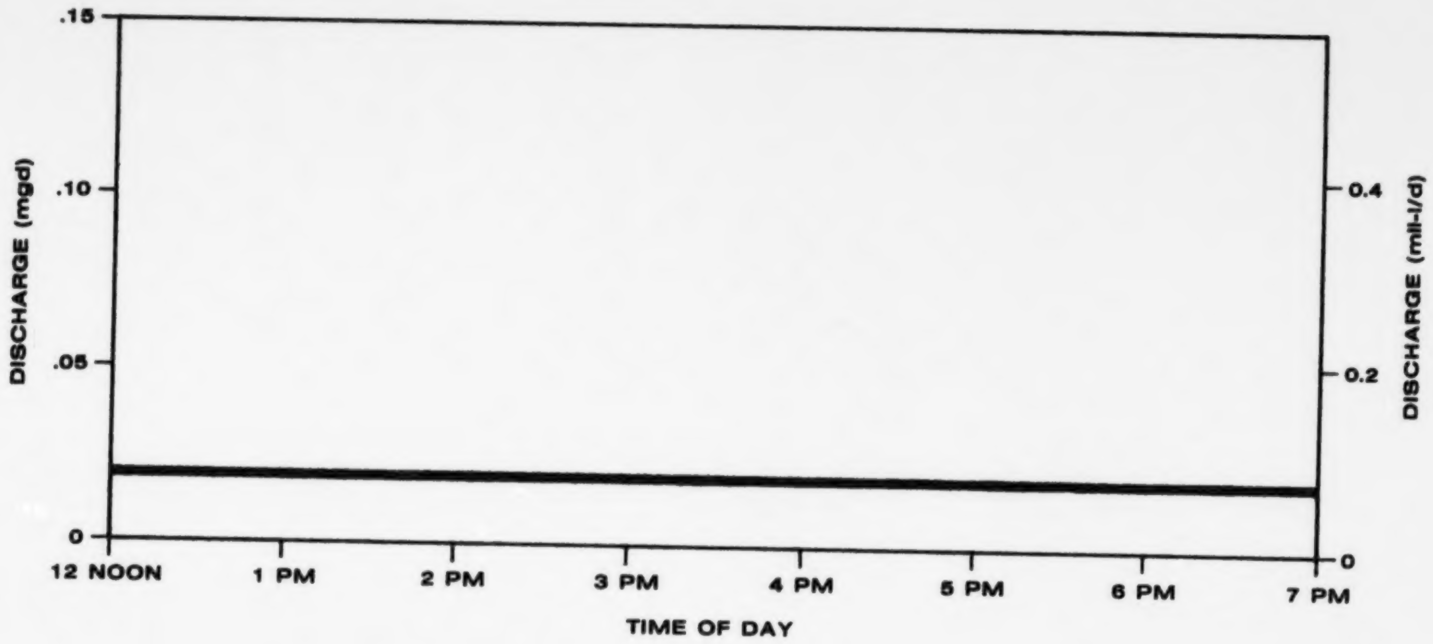


Figure A-8 (continued). Intensive site KY-07-LA runoff hydrograph - April 24-25, 1978.

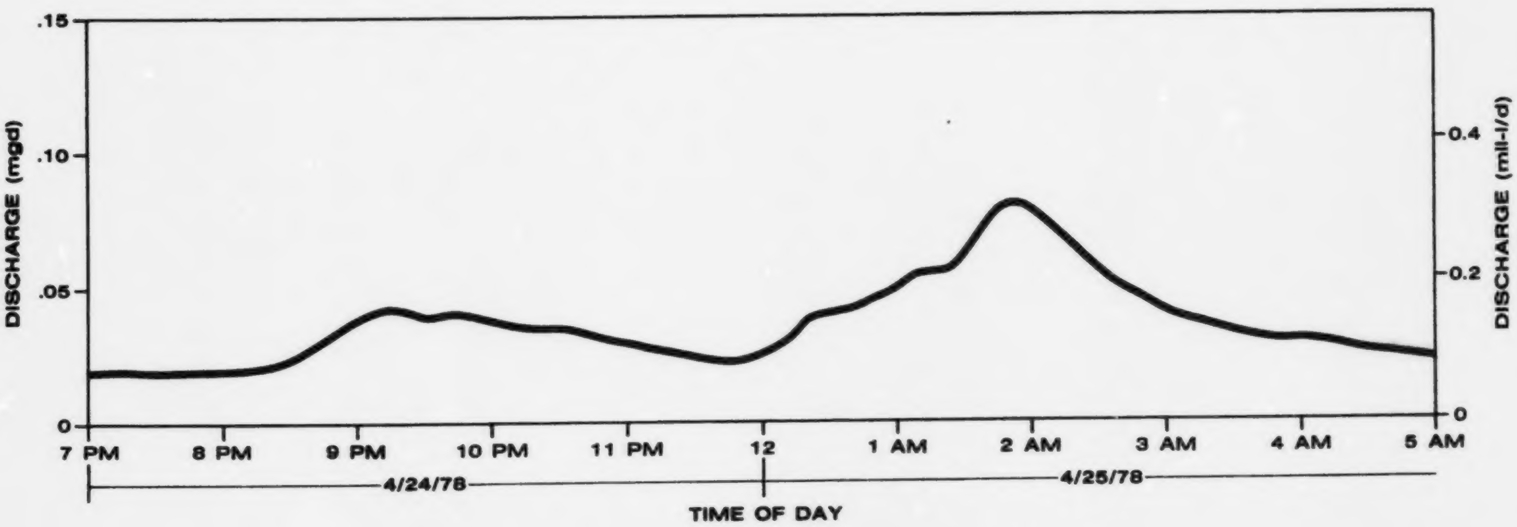


Figure A-8 (continued). Intensive site KY-07-LA runoff hydrograph - April 24-25, 1978.

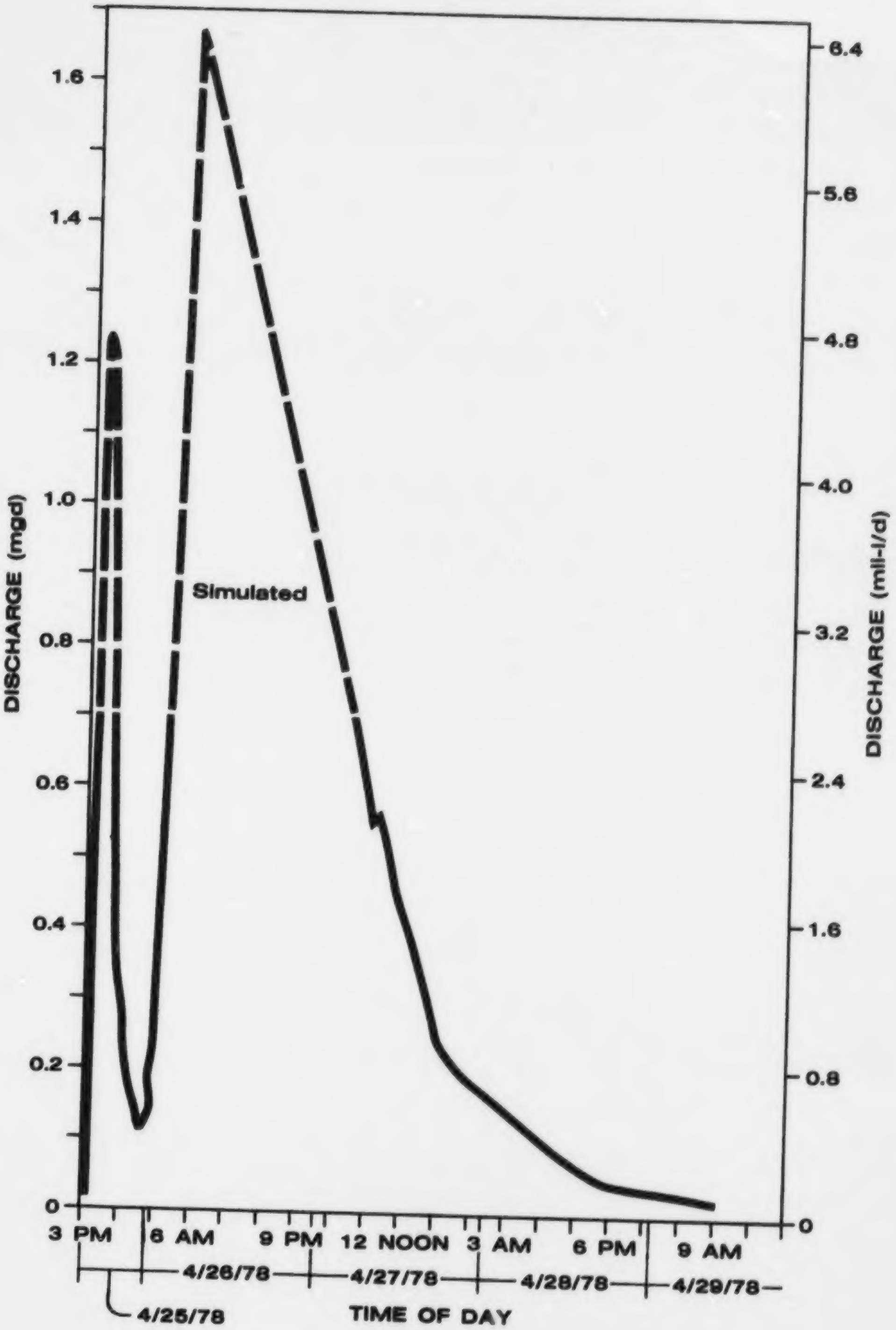


Figure A-9. Intensive site KY-07-LA runoff hydrograph - April 25-29, 1978.

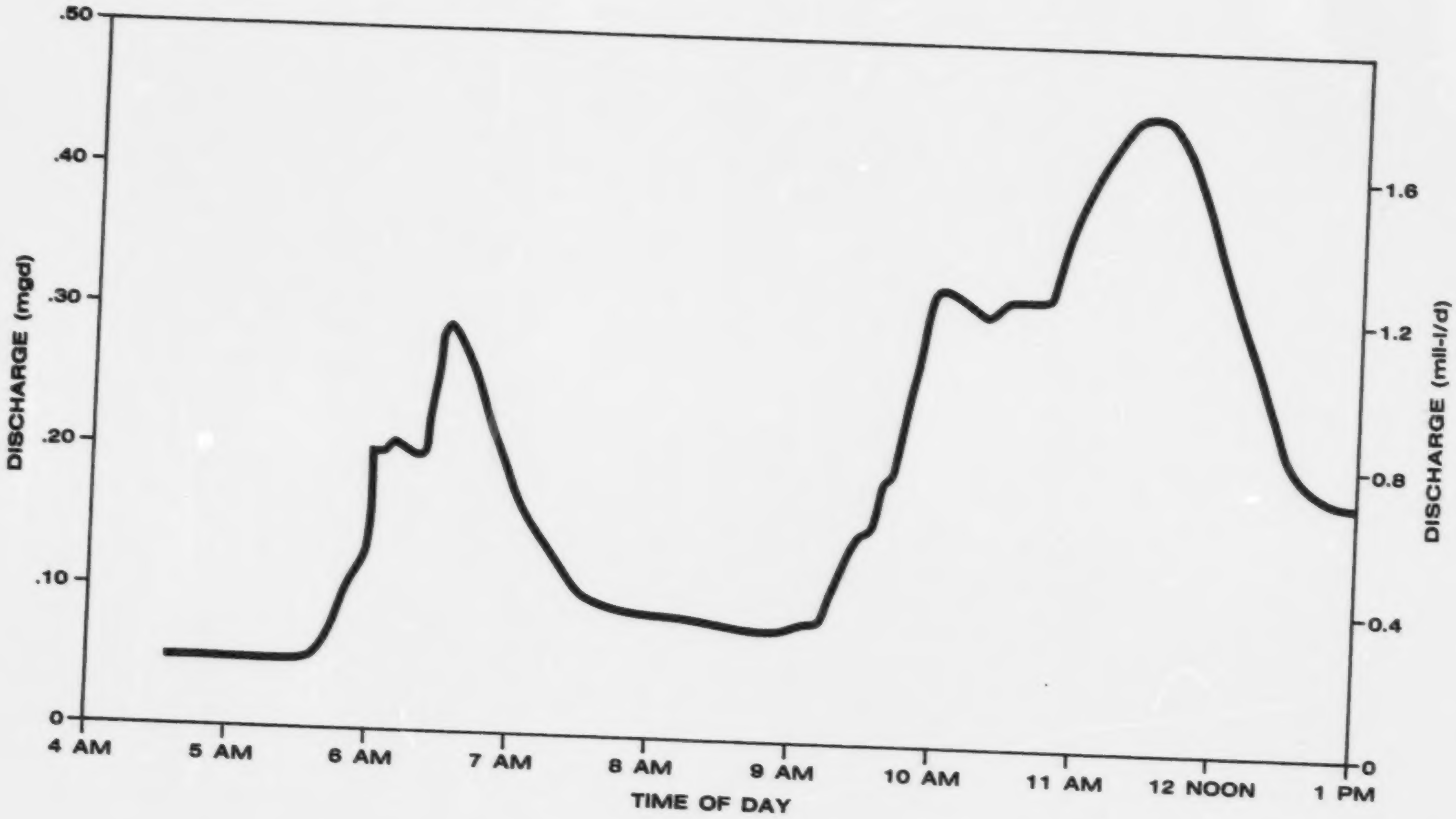


Figure A-10. Intensive site KY-07-LA runoff hydrograph - May 4-5, 1978.

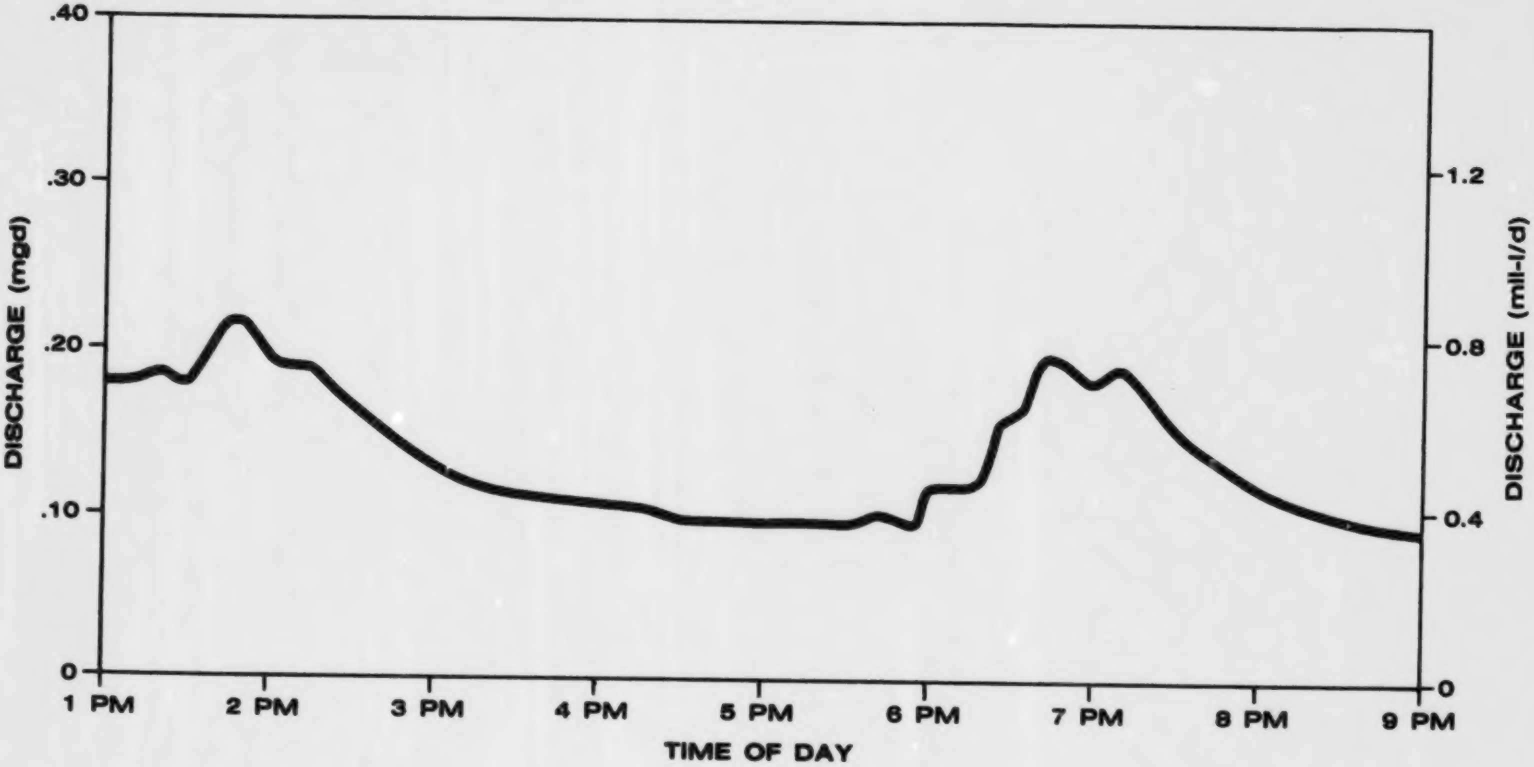


Figure A-10 (continued). Intensive site KY-07-LA runoff hydrograph - May 4-5, 1978.

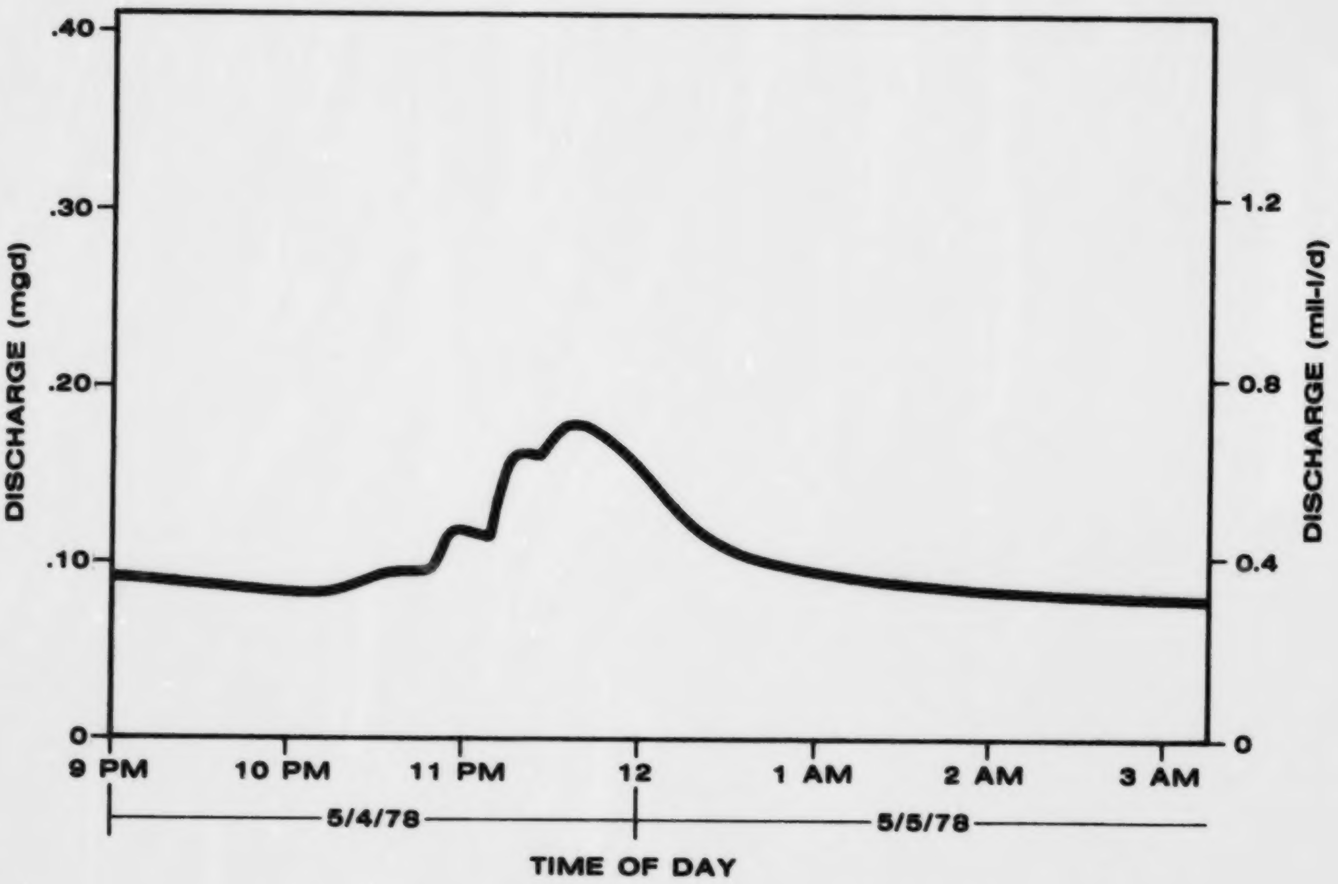


Figure A-10 (continued). Intensive site KY-07-LA runoff hydrograph - May 4-5, 1978.

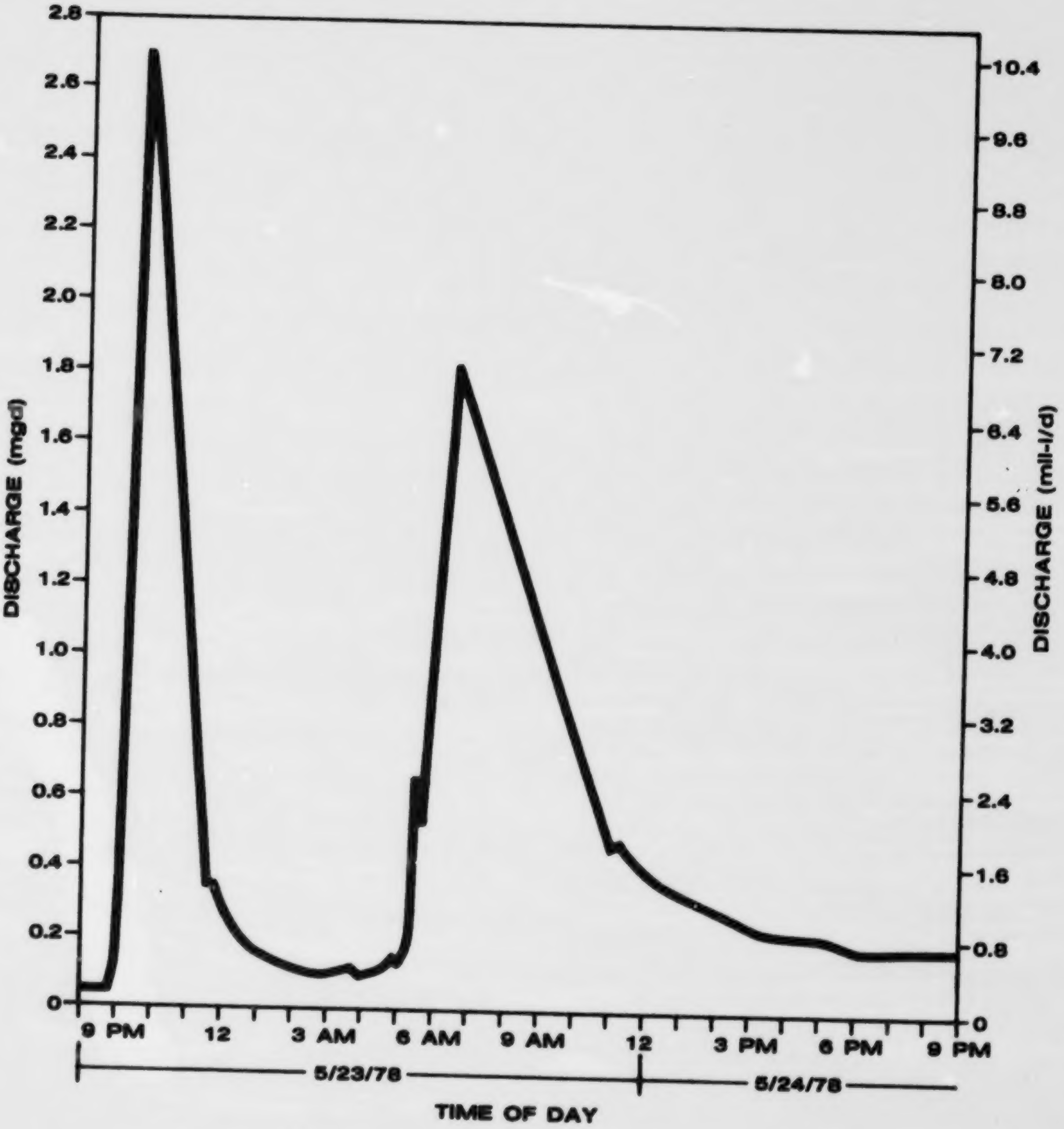


Figure A-11. Intensive site KY-07-LA runoff hydrograph - May 23-24, 1978.

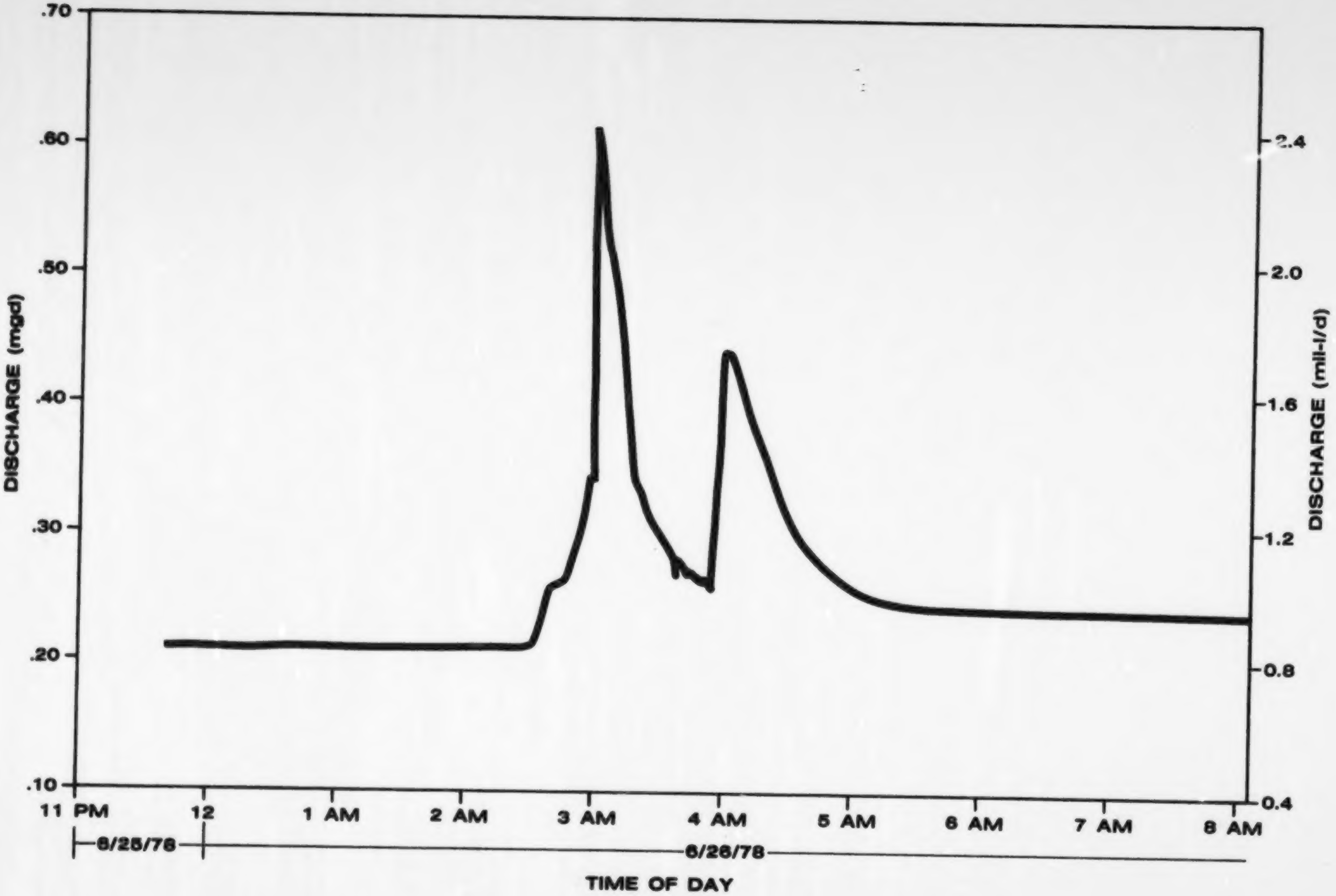


Figure A-12. Intensive site KY-07-LA runoff hydrograph - June 25-26, 1978.

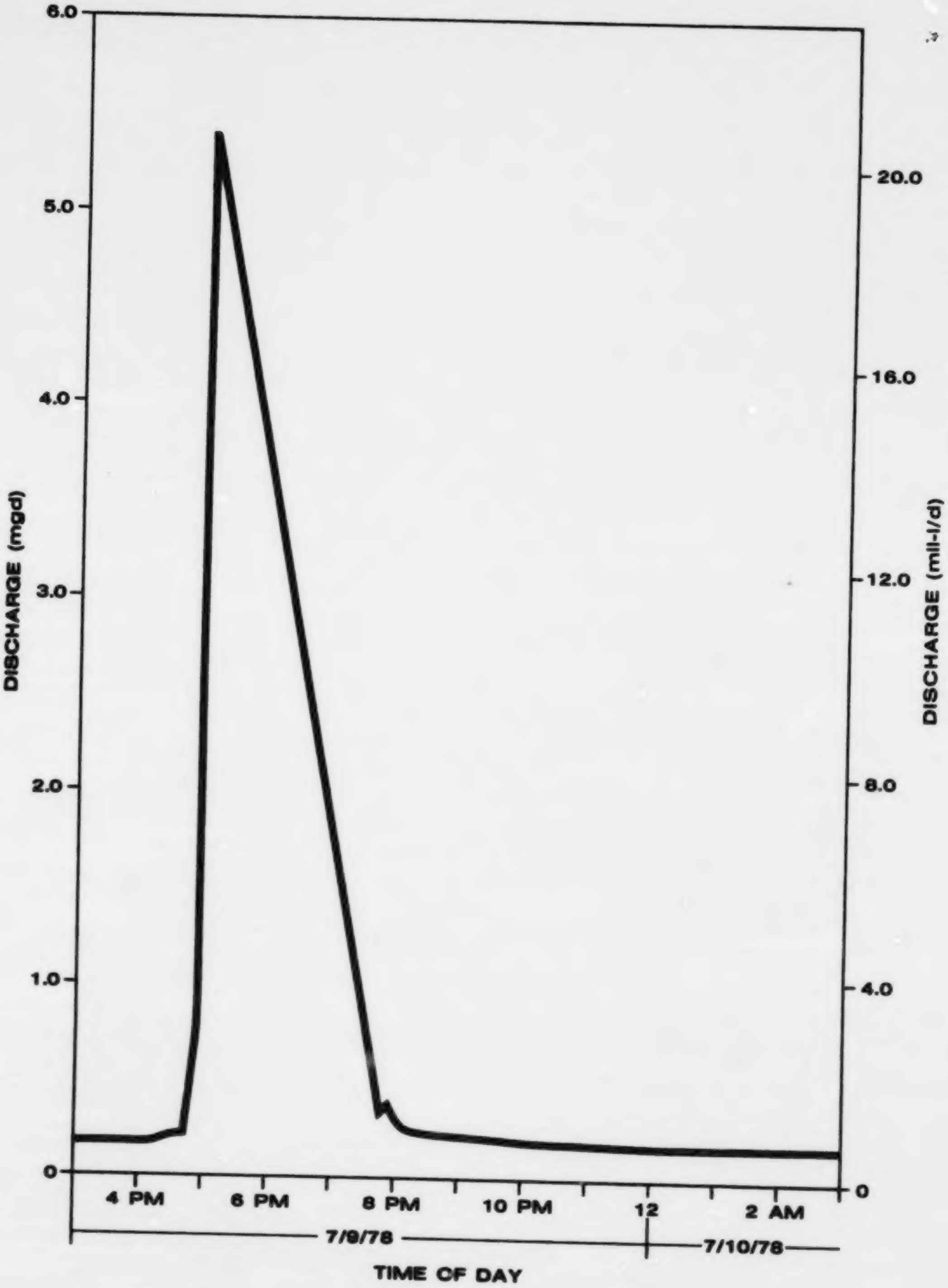


Figure A-13. Intensive site KY-07-LA runoff hydrograph - July 9-10, 1978.

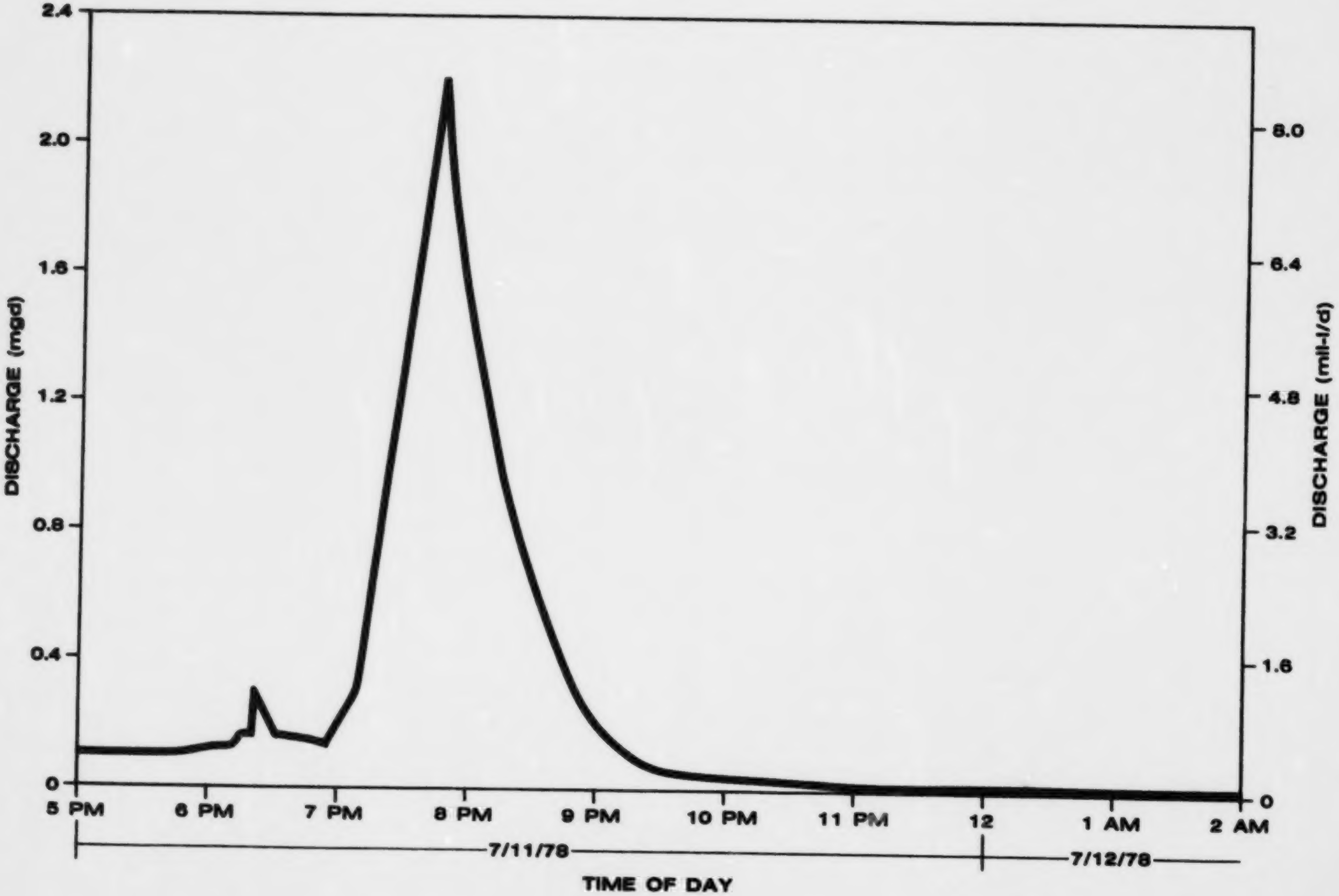


Figure A-14. Intensive site KY-07-LA runoff hydrograph - July 11-12, 1978.

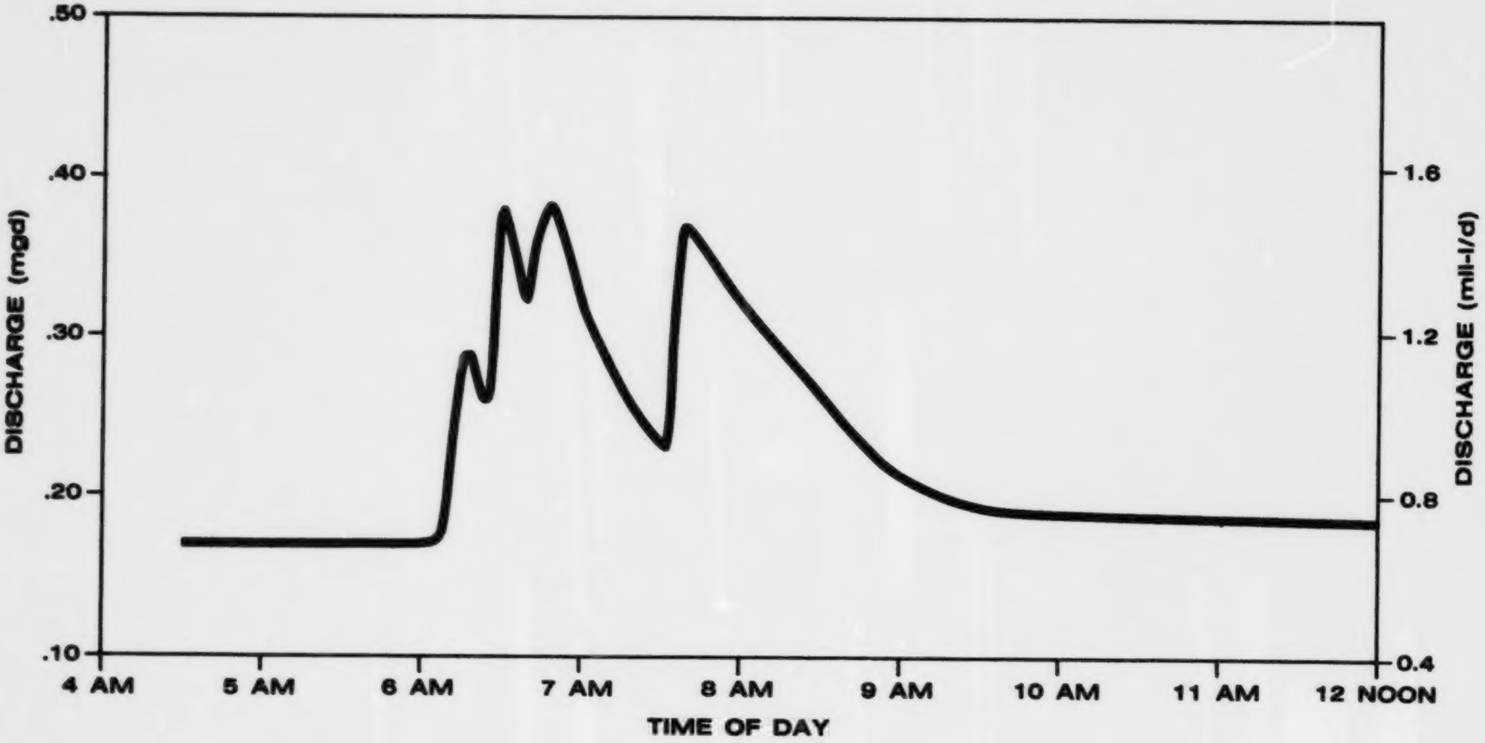


Figure A-15. Intensive site KY-07-LA runoff hydrograph - August 4, 1978.

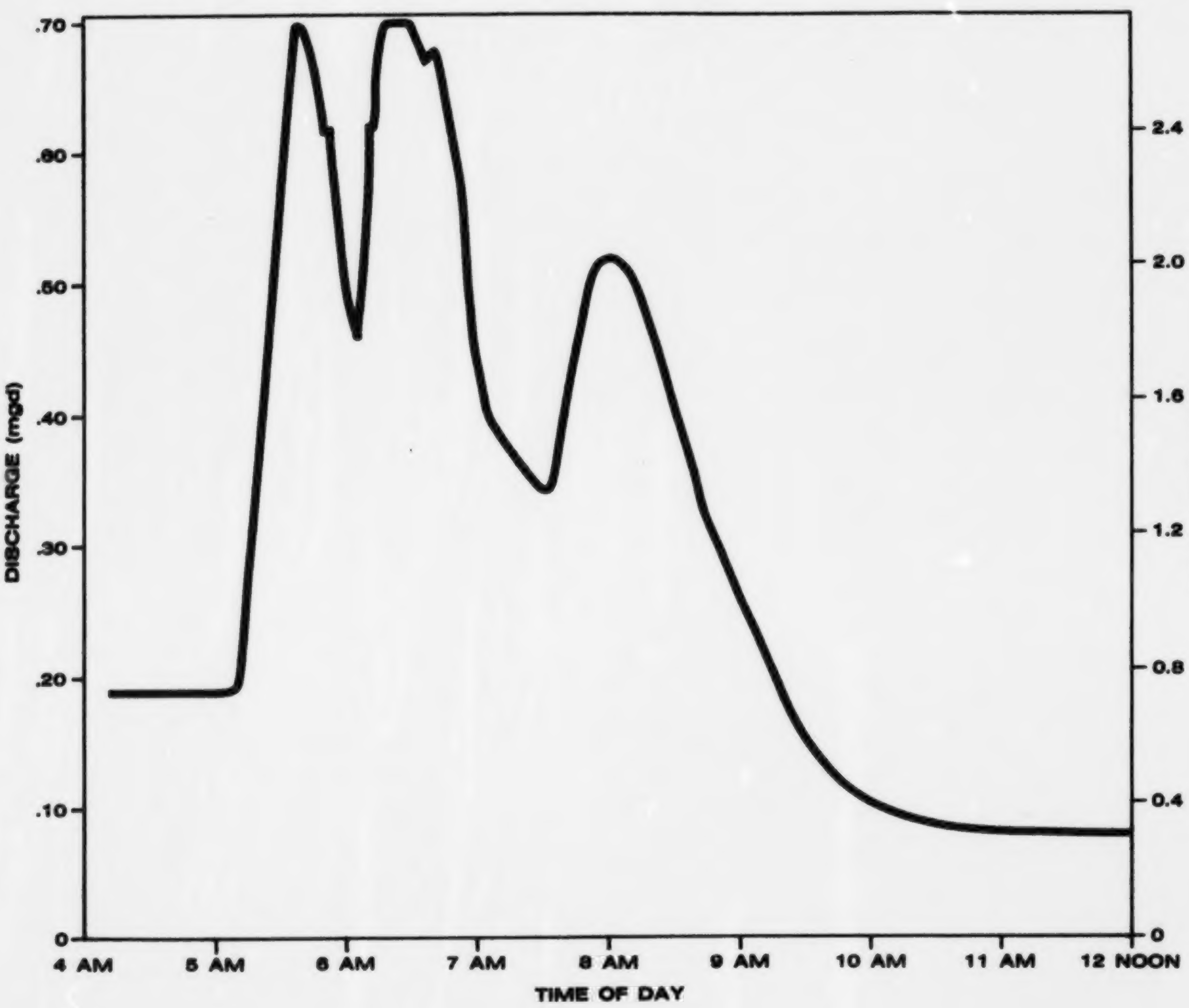


Figure A-16. Intensive site KY-07-LA runoff hydrograph - August 5, 1978.

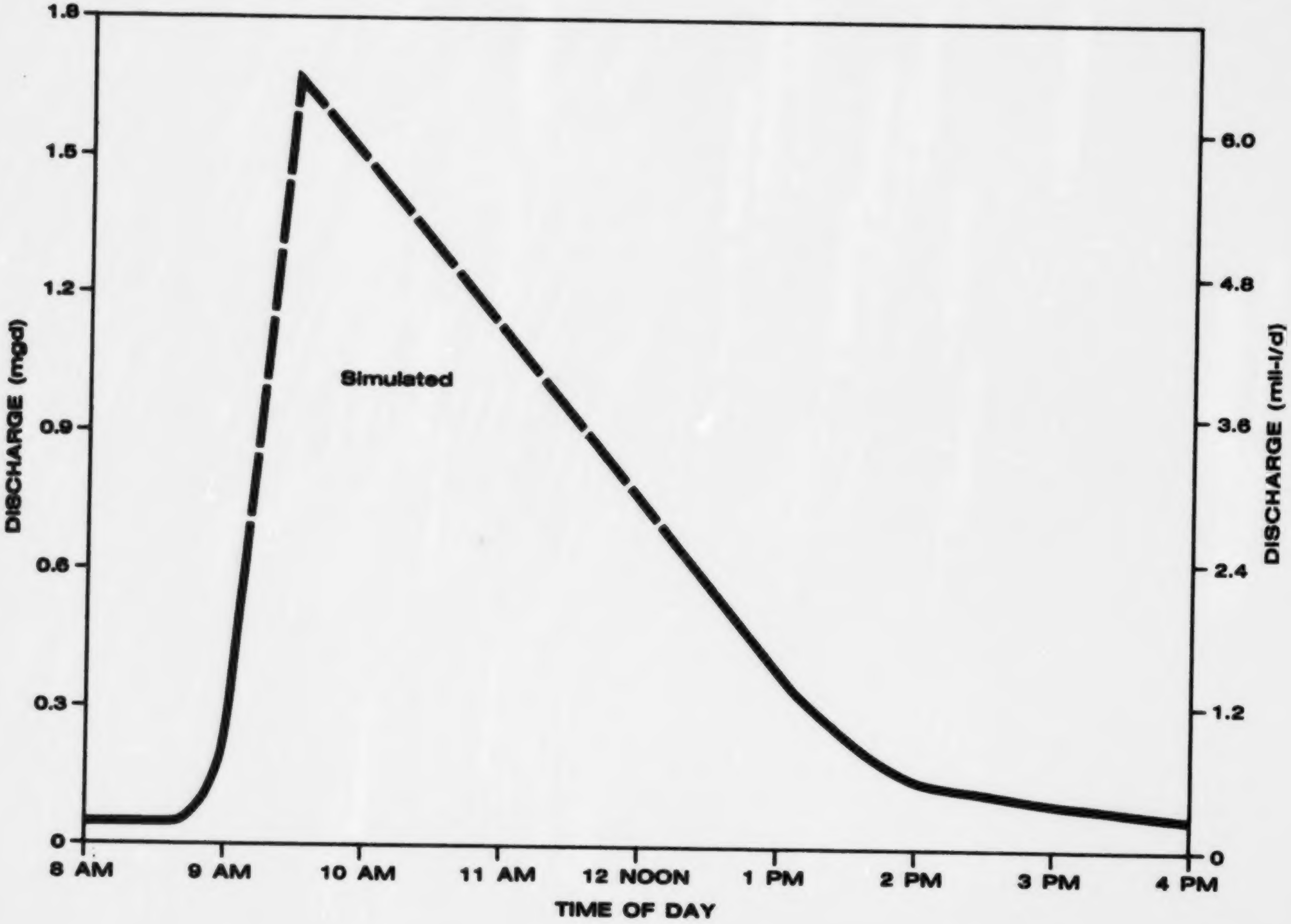


Figure A-17. Intensive site KY-07-LA runoff hydrograph - August 7, 1978.

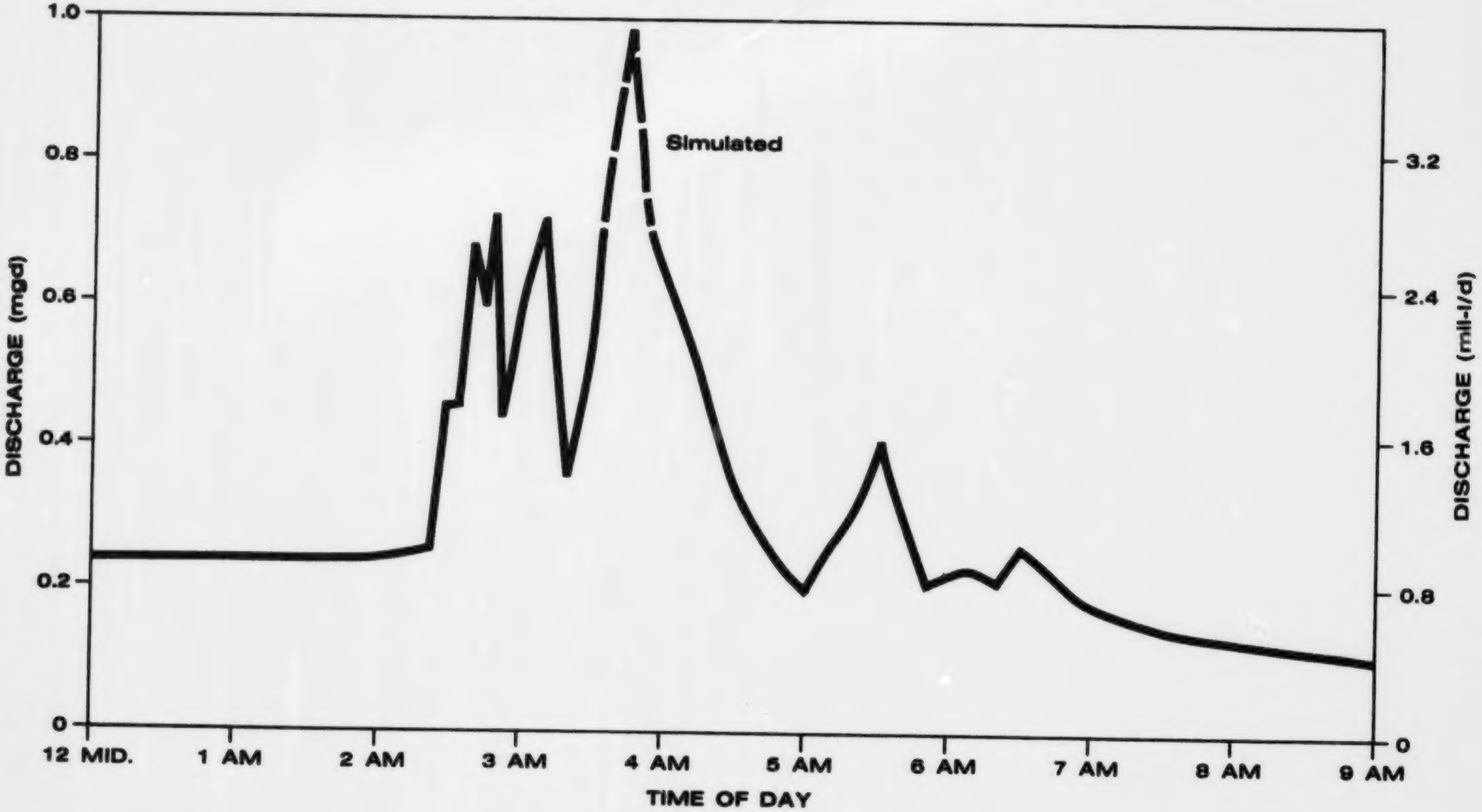


Figure A-18. Intensive site KY-07-LA runoff hydrograph - August 31, 1978.

APPENDIX B
WATER QUALITY DATA
INTENSIVE SITE KY-07-LA

TABLE B-1. WATER QUALITY DATA FROM WEEKLY COMPOSITE SAMPLES COLLECTED UPSTREAM OF THE SEDIMENTATION POND AT INTENSIVE SITE KY-07-LA DURING THE PRE-MINING PERIOD

Week	pH	Total alkalinity (mg/l $CaCO_3$)	Hot acidity (mg/l $CaCO_3$)	Turbidity (JTU)	Total solids (mg/l)	Total iron (mg/l)	Sulfate (mg/l)
1976							
6/24-29	6.1	14	0	<5	104	0.20	4.1
6/30-7/6	6.6	14	0	20	44	0.24	8.0
7/7-13	6.2	14	0	10	38	0.19	7.0
7/14-20	5.7	18	0	30	116	<0.01	16.0
7/28-8/3	7.1	16	0	10	N/A	0.03	9.6
8/4-10	6.4	10	0	10	35	0.02	6.6
8/11-17	6.3	16	6	5	60	0.03	11.0
8/18-24	6.1	18	4	5	60	0.19	10.0
8/25-31	6.9	22	0	<5	34	<0.01	7.5
9/1-7	6.8	22	0	<5	31	<0.01	7.5
9/8-14	6.9	22	0	<5	85	0.01	7.5
9/15-21	7.0	22	0	15	80	<0.01	11.0
9/22-27	6.3	18	2	15	75	<0.01	13.0
9/28-10/5	6.7	14	<2	5	55	<0.01	11.0

TABLE B-2. WATER QUALITY DATA FROM WEEKLY COMPOSITE SAMPLES COLLECTED UPSTREAM OF THE SEDIMENTATION POND AT INTENSIVE SITE KY-07-LA DURING THE ACTIVE MINING PERIOD

Week	pH	Total alkalinity (mg/l $CaCO_3$)	Hot acidity (mg/l $CaCO_3$)	Turbidity (JTU)	Total solids (mg/l)	Total iron (mg/l)	Sulfate (mg/l)
1976							
10/6-12	6.4	10	0	15	65	0.10	12.0
10/13-19	6.5	10	0	5	25	0.01	10.0
10/20-26	6.5	8	6	<5	70	0.14	10.0
11/17-23	6.8	12	2	25	110	0.07	12.0
12/1-7	6.5	10	0	920	700	6.00	13.0
12/15-21	5.8	22	32	100	420	2.70	13.0
12/22-28	5.3	24	18	28	105	0.47	15.0
1977							
1/5-10	5.5	28	18	32	115	0.68	15.0
1/11-17	6.8	24	0	10	100	0.12	15.0
1/18-25	6.6	28	0	21	230	0.10	17.0
1/26-2/2	6.8	38	0	6	120	0.07	12.0
2/3-7	6.6	42	0	19	480	0.58	17.0
2/8-14	6.3	44	20	580	630	8.10	90.0
2/15-21	6.6	50	-20	22	240	0.66	33.0
2/22-28	6.4	50	-20	15	213	0.18	45.0
3/1-7	5.9	48	-12	7	144	0.31	26.0
3/20-24	6.9	50	42	45	157	0.68	27.0
3/26-4/1	6.7	46	36	120	242	1.80	40.0

TABLE B-3. WATER QUALITY DATA FROM WEEKLY COMPOSITE SAMPLES COLLECTED UPSTREAM OF THE SEDIMENTATION POND AT INTENSIVE SITE KY-07-LA DURING THE POST-MINING PERIOD

Week	pH	Total alkalinity (mg/l $CaCO_3$)	Hot acidity (mg/l $CaCO_3$)	Turbidity (JTU)	Total solids (mg/l)	Total iron (mg/l)	Sulfate (mg/l)
1977							
4/19-25	6.0	29	- 48	1250	452	3.4	35.0
5/7-13	7.4	75	- 59	140	405	5.1	52.0
5/21-27	7.7	112	- 90	9	311	0.3	45.0
5/27-6/3	7.5	98	- 94	520	649	2.4	35.0
6/5-11	7.6	96	- 94	45	234	1.1	40.0
6/12-17	6.9	98	- 86	100	517	3.5	55.0
6/20-25	6.8	86	- 76	560	38	23.0	105.0
6/26-27	6.7	102	- 88	750	31545	3.5	160.0
7/2-6	7.5	116	- 80	25	358	0.5	110.0
7/7-13	7.3	110	- 54	760	2795	12.0	150.0
7/15-21	8.0	116	- 28	35	333	0.7	50.0
7/22-28	7.5	90	- 58	>1000	1800	4.4	170.0
7/29-8/4	7.6	134	- 14	900	1398	3.5	150.0
8/5-10	7.5	114	36	330	842	1.5	200.0
8/12-18	7.5	124	-132	920	1452	6.1	210.0
8/20-26	7.7	150	-168	82	660	4.7	140.0
9/2-8	7.3	136	-214	8	329	0.3	110.0

(continued)

TABLE B-3. (continued)

Week	pH	Total alkalinity (mg/l $CaCO_3$)	Hot acidity (mg/l $CaCO_3$)	Turbidity (JTU)	Total solids (mg/l)	Total iron (mg/l)	Sulfate (mg/l)
1977 (cont'd.)							
9/9-12	7.5	158	-168	8	305	0.3	150.0
9/16-21	8.0	154	-172	6	392	0.1	120.0
9/22-29	7.7	140	-140	1320	5740	17.0	150.0
9/30-10/7	8.1	124	-134	500	1110	2.4	140.0
10/9-15	8.0	122	-134	20	391	0.2	140.0
10/18-23	8.0	134	-148	12	343	0.2	110.0
10/24-29	8.0	166	-152	>1000	4990	11.0	125.0
10/30-11/4	7.5	118	-100	>1000	10600	15.0	95.0
11/7-12	6.8	118	- 82	>1000	29600	170.0	130.0
11/14-19	7.8	36	- 2	12	353	0.3	87.0
11/20-26	7.6	94	- 88	320	1152	15.0	97.0
11/28-12/4	7.2	90	- 80	740	6410	53.0	95.0
12/12-17	7.2	100	- 60	300	6420	84.0	210.0
12/18-25	7.4	114	-108	250	690	6.6	190.0

(continued)

TABLE B-3. (continued)

Week	pH	Total alkalinity (mg/l CaCO3)	Hot acidity (mg/l CaCO3)	Turbidity (JTU)	Total solids (mg/l)	Total iron (mg/l)	Sulfate (mg/l)
1978							
1/2-8	6.4	86	- 58	290	710	5.0	115.0
1/9-15	7.7	70	- 48	25	310	0.5	140.0
1/16-22	7.7	74	- 48	550	1000	6.9	170.0
1/23-29	7.0	82	- 16	800	3409	4.3	171.0
1/30-2/5	7.7	114	- 66	120	1028	1.1	316.0
2/6-12	7.7	102	- 54	41	744	0.6	238.0
2/13-18	7.6	90	- 46	69	587	0.7	146.0
2/20-26	7.3	86	- 60	180	852	4.9	275.0
2/27-3/5	7.5	90	- 66	20	297	0.4	305.0
3/13-19	7.5	112	- 86	740	1553	16.0	450.0
3/20-26	7.5	96	- 92	64	747	1.5	370.0
3/27-4/2	7.8	124	-112	16	915	0.7	500.0
4/3-9	8.0	132	-114	35	712	1.5	440.0
4/10-12	8.3	138	-202	4	773	0.2	405.0
4/15-20	8.2	120	-206	98	817	4.6	325.0
4/21-26	7.2	34	18	150	634	8.4	27.0
4/27-30	8.1	100	-162	260	1040	8.3	325.0
5/1-7	8.2	128	-208	215	1480	11.6	395.0

(continued)

TABLE B-3. (continued)

Week	pH	Total alkalinity (mg/l CaCO$_3$)	Hot acidity (mg/l CaCO$_3$)	Turbidity (JTU)	Total solids (mg/l)	Total iron (mg/l)	Sulfate (mg/l)
1978 (cont'd.)							
5/9-14	7.4	110	- 90	400	556*	11.7	340.0
5/15-20	7.8	114	- 98	40	76*	1.5	410.0
5/22-28	7.6	112	- 96	24	66*	1.0	370.0
5/29-6/4	7.7	132	-114	130	210*	5.0	370.0
6/5-11	7.5	130	-112	300	454*	10.9	315.0
6/12-17	7.5	134	-116	170	266*	7.0	305.0
6/19-25	7.0	136	-120	112	336	2.0	240.0
6/26-7/2	7.2	134	-116	192	410	3.2	210.0
7/3-9	7.7	138	-124	880	1367	7.7	280.0
7/10-16	7.5	134	-130	330	515	3.4	295.0
7/17-23	7.9	144	-140	6	17	0.5	265.0
7/24-30	7.5	146	-140	52	67	0.8	250.0
7/31-8/6	7.4	146	-140	470	697	4.8	260.0
8/7-13	7.8	150	-154	350	194	3.8	250.0
8/14-20	8.1	150	-152	140	248	1.7	240.0
8/21-27	7.9	158	-160	84	239	1.1	260.0
8/29-9/4	7.7	148	-148	250	378	2.3	270.0
9/5-10	7.9	144	-142	99	447	1.7	250.0

*Values are suspended solids (mg/l).

TABLE B-4. WATER QUALITY DATA FROM WEEKLY GRAB SAMPLES COLLECTED AT THE EFFLUENT OF THE SEDIMENTATION POND AT INTENSIVE SITE KY-07-LA DURING THE ACTIVE MINING PERIOD

Week	Turbidity (JTU)	Suspended solids (mg/l)
1977		
1/5-10	14	14
1/11-17	6	6
1/18-25	5	36
1/26-2/2	6	39
2/3-7	4	31
2/8-14	52	37
2/15-21	94	56
2/22-28	110	37
3/1-7	22	41
3/26-4/1	42	2168

TABLE B-5. WATER QUALITY DATA FROM WEEKLY GRAB SAMPLES COLLECTED AT THE EFFLUENT OF THE SEDIMENTATION POND AT INTENSIVE SITE KY-07-LA DURING THE POST-MINING PERIOD

Week	Turbidity (JTU)	Suspended solids (mg/l)	Week	Turbidity (JTU)	Suspended solids (mg/l)	Week	Turbidity (JTU)	Suspended solids (mg/l)
1977								
4/13-19	25	45	10/30-11/4	160	246	4/19-23	25	55
4/29-5/6	120	98	11/5-12	20	27	4/27-30	290	488
5/7-13	650	670	11/14-19	2	3	5/2-7	140	272
5/23-26	11	14	11/20-27	4	183	5/8-10	290	398
5/28-6/3	68	106	11/28-12/4	220	54	5/15-17	1960	1280
6/5-11	18	37	12/19-21	520	195	5/22-28	100	144
6/14-16	25	35	12/26-30	4	30	5/29-6/1	760	806
6/22-24	310	424				6/5-11	>1000	988
6/26-28	90	43	1978			6/12-15	>1000	990
7/3-7	130	145				6/19-25	36	60
7/15-21	70	252	1/4-6	100	420	6/27-7/2	>1000	1322
7/22-28	540	466	1/10-12	78	105	7/8-9	410	494
7/29-8/4	1000	1488	1/17-20	720	770	7/11-16	960	963
8/5-10	190	386	1/24-29	300	631	7/19-23	6	21
8/12-14	1280	6852	1/30-2/1	250	290	7/24-29	24	7
8/20-25	110	400	2/6-8	59	96	7/31-8/6	27	45
9/2-8	2	22	2/12-14	100	148	8/7-13	370	464
9/9-14	10	39	2/20-22	250	566	8/15-20	23	54
9/17-20	6	32	2/27-28	17	19	8/21-25	39	110
9/21-28	3	11	3/12-14	990	1182	8/30-9/3	58	124
9/29-10/5	7	34	3/20-22	58	135	9/4-10	110	141
10/10-15	18	64	3/28-30	120	216			
10/20-23	55	92	4/4-7	3	20			
10/24-29	7	41	4/10-12	3	9			

TABLE B-6. WATER QUALITY DATA FROM MONTHLY COMPOSITE SAMPLES COLLECTED UPSTREAM OF THE SEDIMENTATION POND AT INTENSIVE SITE KY-07-LA DURING THE ACTIVE AND POST-MINING PERIODS

	Active mining 1977			Post-mining 1977		
	February	March	April	June	September	October
pH	6.5	7.4	7.8	7.7	7.9	7.9
Total alkalinity (mg/l $CaCO_3$)	54	46	82	90	150	146
Hot acidity (mg/l $CaCO_3$)	-16	-22	-74	-82	-142	-142
Turbidity (JTU)	93	90	160	950	>1000	>1000
Total solids (mg/l)	223	190	480	2380	6800	4540
Suspended solids (mg/l)	75	70	284	1980	6420	4260
Conductivity (µmhos/cm)	240	160	265	435	490	450
Sulfate (mg/l)	30	30	55	130	130	130
Calcium (mg/l)	15	15	35	47	56	47
Magnesium (mg/l)	16	10	20	28	27	28
Manganese (mg/l)	0.8	0.4	1.3	2.0	2.5	0.8
Total iron (mg/l)	0.3	0.6	2.4	8.3	14.0	5.8
Dissolved iron (mg/l)	0.1	0.1	0.1	0.4	0.4	0.1
Aluminum (mg/l)	0.2	0.2	0.7	5.8	11.0	6.7
Copper (mg/l)	<0.01	<0.01	<0.01	0.01	0.05	0.01
Zinc (mg/l)	0.03	0.03	0.03	0.28	0.23	0.12
Cadmium (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel (mg/l)	<0.03	<0.03	<0.03	0.03	0.08	0.04

(continued)

TABLE B-6. (continued)

	Post-mining 1977		Post-mining 1978		
	November	December	January	April	May
pH	7.0	6.4	7.6	7.3	7.6
Total alkalinity (mg/l $CaCO_3$)	42	90	96	104	122
Hot acidity (mg/l $CaCO_3$)	-18	-30	-70	-88	-102
Turbidity (JTU)	90	100	40	200	160
Total solids (mg/l)	397	17200	537	992	968
Suspended solids (mg/l)	250	17200	175	404	292
Conductivity (µmhos/cm)	180	530	430	710	920
Sulfate (mg/l)	50	190	170	315	360
Calcium (mg/l)	18	53	47	85	106
Magnesium (mg/l)	9	39	27	53	64
Manganese (mg/l)	0.6	7.7	0.9	1.1	0.7
Total iron (mg/l)	3.7	116.0	2.8	9.8	6.9
Dissolved iron (mg/l)	0.0	0.1	0.0	0.0	0.0
Aluminum (mg/l)	2.3	56.0	1.4	7.5	5.8
Copper (mg/l)	0.02	0.17	0.02	0.04	0.07
Zinc (mg/l)	0.05	0.44	0.03	0.08	0.05
Cadmium (mg/l)	<0.01	0.01	<0.01	<0.01	<0.01
Nickel (mg/l)	<0.03	0.20	<0.03	0.05	0.04

TABLE B-7. WATER QUALITY DATA FROM MONTHLY COMPOSITE SAMPLES COLLECTED AT THE EFFLUENT OF THE SEDIMENTATION POND AT INTENSIVE SITE KY-07-LA DURING THE ACTIVE AND POST-MINING PERIODS

	Active mining 1977		Post-mining 1977				
	February	March	April	May	June	July	August
pH	6.6	7.2	7.8	8.1	7.8	7.8	8.0
Total alkalinity (mg/l $CaCO_3$)	30	32	78	116	108	108	122
Hot acidity (mg/l $CaCO_3$)	10	19	-54	-120	-112	-112	-128
Turbidity (JTU)	24	160	780	80	150	>1000	>1000
Total solids (mg/l)	116	264	2120	331	475	3500	1541
Suspended solids (mg/l)	42	166	1840	114	230	3060	1180
Conductivity (µmhos/cm)	120	125	285	345	365	470	500
Sulfate (mg/l)	20	30	80	65	85	150	160
Calcium (mg/l)	6	18	37	31	30	46	46
Magnesium (mg/l)	7	7	23	21	17	25	34
Manganese (mg/l)	0.0	0.4	2.0	1.0	1.0	2.9	2.0
Total iron (mg/l)	0.4	1.6	14.0	1.4	1.6	11.0	5.2
Dissolved iron (mg/l)	0.3	0.2	0.3	0.0	0.1	0.1	0.1
Aluminum (mg/l)	0.6	0.5	5.0	0.8	1.5	7.2	4.2
Copper (mg/l)	<0.01	<0.01	0.01	<0.01	<0.01	0.04	0.01
Zinc (mg/l)	0.01	0.05	0.07	0.12	<0.01	0.08	0.05
Cadmium (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel (mg/l)	<0.03	<0.03	<0.03	<0.03	<0.03	0.04	<0.03

(continued)

TABLE B-7. (continued)

	Post-mining 1977 September	October	November	December
pH	7.9	7.8	7.6	7.6
Total alkalinity (mg/l $CaCO_3$)	156	102	106	112
Hot acidity (mg/l $CaCO_3$)	-164	-104	-78	-82
Turbidity (JTU)	35	70	130	800
Total solids (mg/l)	380	380	486	1370
Suspended solids (mg/l)	60	98	211	826
Conductivity (µmhos/cm)	480	415	380	490
Sulfate (mg/l)	140	200	125	210
Calcium (mg/l)	53	40	42	54
Magnesium (mg/l)	28	24	24	33
Manganese (mg/l)	1.0	1.0	1.2	2.0
Total iron (mg/l)	0.8	1.1	3.7	17.2
Dissolved iron (mg/l)	0.0	0.0	0.0	0.0
Aluminum (mg/l)	0.4	0.8	2.2	10.9
Copper (mg/l)	<0.01	<0.01	0.02	0.03
Zinc (mg/l)	0.15	0.20	0.04	4.50
Cadmium (mg/l)	<0.01	<0.01	<0.01	<0.01
Nickel (mg/l)	<0.03	<0.03	<0.03	<0.03

(continued)

TABLE B-7. (continued)

	Post-mining 1978 January	February	March	April	May
pH	7.5	7.6	7.6	7.7	7.6
Total alkalinity (mg/l $CaCO_3$)	86	98	110	116	106
Hot acidity (mg/l $CaCO_3$)	-59	-82	-92	-100	-88
Turbidity (JTU)	310	130	420	120	780
Total solids (mg/l)	1060	835	1360	914	1520
Suspended solids (mg/l)	482	250	582	234	890
Conductivity (µmhos/cm)	740	820	920	820	820
Sulfate (mg/l)	350	330	430	370	330
Calcium (mg/l)	72	67	93	83	72
Magnesium (mg/l)	46	46	61	54	47
Manganese (mg/l)	1.5	1.2	1.6	1.3	1.3
Total iron (mg/l)	7.5	5.2	12.5	5.0	20.0
Dissolved iron (mg/l)	0.0	0.1	0.1	0.0	0.0
Aluminum (mg/l)	4.9	3.7	9.5	3.6	11.9
Copper (mg/l)	0.03	0.03	0.03	0.02	0.03
Zinc (mg/l)	0.19	0.04	0.11	0.05	0.08
Cadmium (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel (mg/l)	<0.03	0.03	0.05	0.04	0.05

APPENDIX C
WOODY VEGETATION DATA
INTENSIVE SITE KY-07-LA

TABLE C-1. TREE SPECIES DATA COLLECTED THROUGH RANDOM PAIRS SAMPLING AT INTENSIVE SITE KY-07-LA

	Point			Tree diameter		Distance A to B	
Transect no.	No.	Pairs	Species	(cm)	(in)	(m)	(ft)
T-1	1	A	white oak	10.4	4.1	4.5	14.7
(east slope)		B	white oak	23.1	9.1		
	2	A	white oak	21.1	8.3	4.3	14.3
		B	white oak	27.4	10.8		
	3	A	white oak	25.7	10.1	4.3	14.0
		B	white oak	14.2	5.6		
	4	A	white oak	30.5	12.0	8.6	28.4
		B	white oak	23.9	9.4		
	5	A	white oak	14.5	5.7	5.0	16.6
		B	white oak	42.2	16.6		
T-2	1	A	white oak	20.6	8.1	4.7	15.5
		B	white oak	15.0	5.9		
	2	A	white oak	11.4	4.5	6.0	19.9
		B	white oak	14.5	5.7		
	3	A	white oak	14.2	5.6	3.4	11.2
		B	white oak	13.0	5.1		
	4	A	white oak	14.5	5.7	9.5	31.4
		B	white oak	25.9	10.2		
	5	A	white oak	23.4	9.2	4.0	13.1
		B	white oak	20.3	8.0		
	6	A	white oak	15.2	6.0	4.7	15.4
		B	white oak	15.5	6.1		
	7	A	black walnut	21.8	8.6	11.8	38.7
		B	white oak	38.9	15.3		
T-3	1	A	American beech	17.8	7.0	4.3	14.1
		B	white oak	16.3	6.4		
	2	A	American beech	16.3	6.4	2.2	7.2
		B	white oak	17.3	6.8		

(continued)

TABLE C-1. (continued)

Transect no.	Point No.	Point Pairs	Species	Tree diameter (cm)	Tree diameter (in)	Distance A to B (m)	Distance A to B (ft)
T-3 (Cont'd.)	3	A	white oak	17.0	6.7	3.6	11.8
		B	white oak	20.3	8.0		
	4	A	American beech	64.3	25.3	9.6	31.5
		B	American beech	58.2	22.9		
T-4	1	A	black oak	50.3	19.8	11.9	39.0
		B	black oak	14.0	5.5		
	2	A	chestnut oak	37.1	14.6	3.8	12.5
		B	black oak	10.4	4.1		
	3	A	black oak	29.0	11.4	6.2	20.3
		B	black oak	14.0	5.5		
	4	A	shagbark hickory	15.2	6.0	8.4	27.5
		B	flowering dogwood	20.1	7.9		
	5	A	white oak	24.1	9.5	4.0	13.0
		B	white oak	22.1	8.7		
T-5 (below hollow fill #7)	1	A	white oak	45.7	18.0	17.3	57.0
		B	black oak	11.7	4.6		
	2	A	white oak	14.5	5.7	5.9	19.5
		B	white oak	35.8	14.1		
	3	A	American beech	15.5	6.1	6.7	22.0
		B	black oak	32.5	12.8		
T-6 (west slope of hollow)	1	A	sassafras	13.2	5.2	1.9	6.4
		B	American beech	11.7	4.6		
	2	A	table mountain pine	10.4	4.1	6.8	22.3
		B	yellow-poplar	13.2	5.2		
	3	A	yellow-poplar	22.6	8.9	6.5	21.3
		B	yellow-poplar	36.3	14.3		
	4	A	flowering dogwood	10.9	4.3	11.6	38.2
		B	shagbark hickory	16.3	6.4		
	5	A	shagbark hickory	29.5	11.6	9.1	29.9
		B	white oak	17.5	6.9		

(continued)

TABLE C-1. (continued)

Transect no.	Point		Species	Tree diameter		Distance A to B	
	No.	Pairs		(cm)	(in)	(m)	(ft)
T-7	1	A	shagbark hickory	10.4	4.1	4.0	13.3
		B	chestnut oak	21.8	8.6		
	2	A	black oak	56.6	22.3	8.8	28.8
		B	American beech	16.3	6.4		
	3	A	black birch	11.2	4.4	1.2	4.0
		B	shagbark hickory	12.7	5.0		
	4	A	shagbark hickory	16.8	6.6	6.1	20.0
		B	table mountain pine	23.6	9.3		
	5	A	sycamore	14.0	5.5	11.1	36.6
		B	yellow-poplar	27.7	10.9		
	6	A	yellow-poplar	17.5	6.9	5.3	17.4
		B	yellow-poplar	15.5	6.1		
	7	A	sassafras	12.2	4.8	8.6	28.3
		B	yellow-poplar	21.1	8.3		
T-8	1	A	white oak	32.5	12.8	6.7	22.0
		B	black oak	27.7	10.9		
	2	A	sugar maple	15.0	5.9	3.2	10.5
		B	chestnut oak	69.1	27.2		
	3	A	sugar maple	18.5	7.3	2.7	8.8
		B	sugar maple	23.6	9.3		
	4	A	sugar maple	20.6	8.1	6.5	21.4
		B	black oak	11.2	4.4		
	5	A	red maple	13.0	5.1	4.6	15.0
		B	white oak	10.4	4.1		
	6	A	red maple	10.2	4.0	9.5	31.3
		B	chestnut oak	19.3	7.6		
	7	A	flowering dogwood	14.5	5.7	8.4	27.7
		B	sugar maple	11.9	4.7		
	8	A	chokecherry	10.4	4.1	4.8	15.9
		B	flowering dogwood	15.0	5.9		

(continued)

TABLE C-1. (continued)

Transect no.	Point No.	Pairs	Species	Tree diameter (cm)	Tree diameter (in)	Distance A to B (m)	Distance A to B (ft)
T-9	1	A	yellow-poplar	12.4	4.9	6.0	19.8
		B	sycamore	11.7	4.6		
	2	A	red maple	12.7	5.0	8.8	28.9
		B	American beech	66.8	26.3		
	3	A	black birch	10.4	4.1	7.1	23.3
		B	red maple	18.8	7.4		
	4	A	chestnut oak	11.4	4.5	6.6	21.7
		B	red maple	18.0	7.1		
	5	A	chestnut oak	14.2	5.6	4.5	14.8
		B	white oak	15.7	6.2		
	6	A	black oak	26.2	10.3	4.1	13.5
		B	black oak	34.5	13.6		
	7	A	black oak	14.7	5.8	4.0	13.3
		B	white oak	13.2	5.2		
	8	A	white oak	22.9	9.0	6.7	22.2
		B	black oak	36.3	14.3		
	9	A	black oak	61.4	24.2	1.7	5.7
		B	black oak	27.2	10.7		
	10	A	black oak	23.9	9.4	4.7	15.4
		B	black oak	16.0	6.3		

APPENDIX D
STORM HYDROGRAPHS
INTENSIVE SITE WV-07-SA

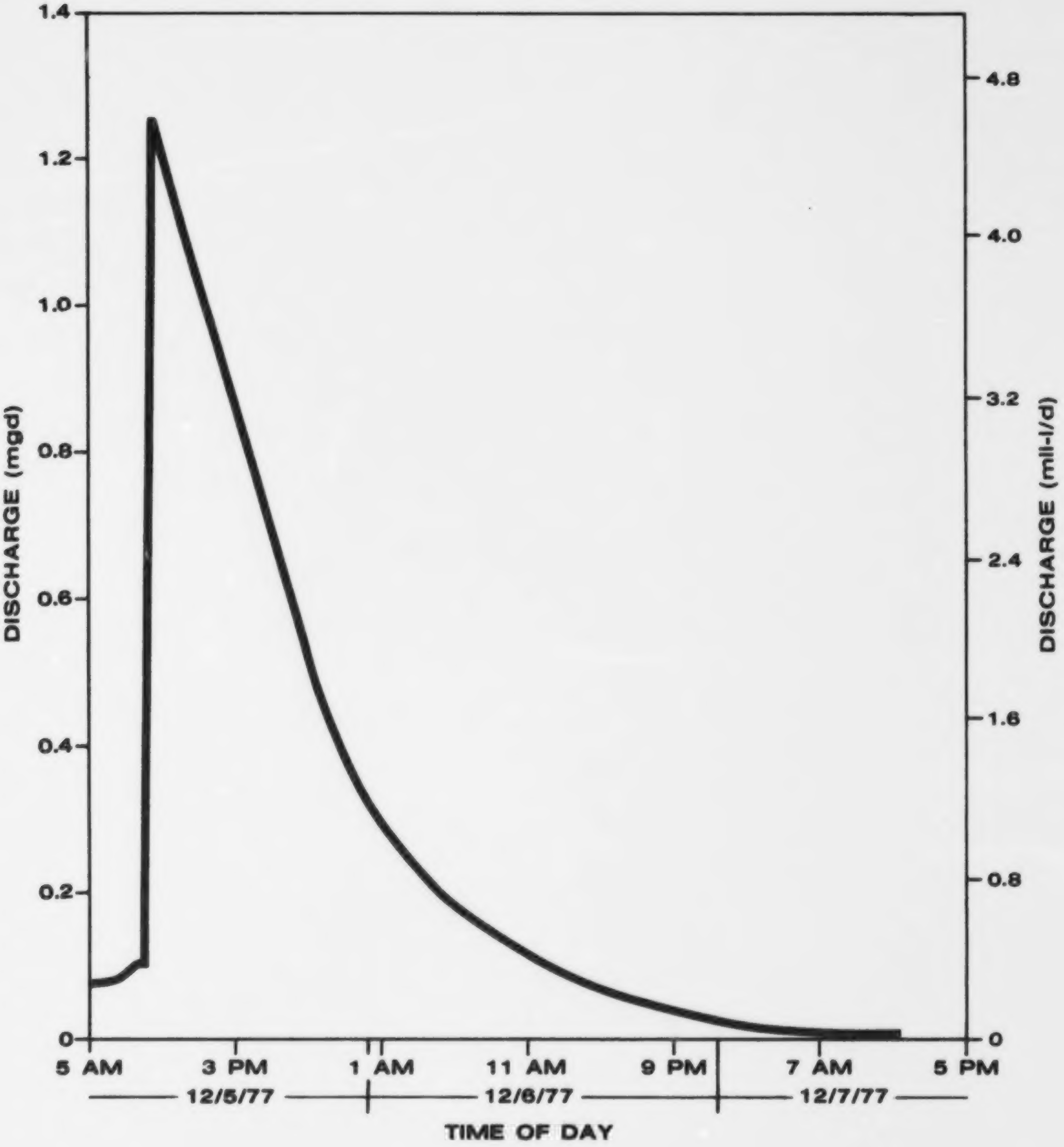


Figure D-1. Intensive site WV-07-SA runoff hydrograph - December 5-7, 1977.

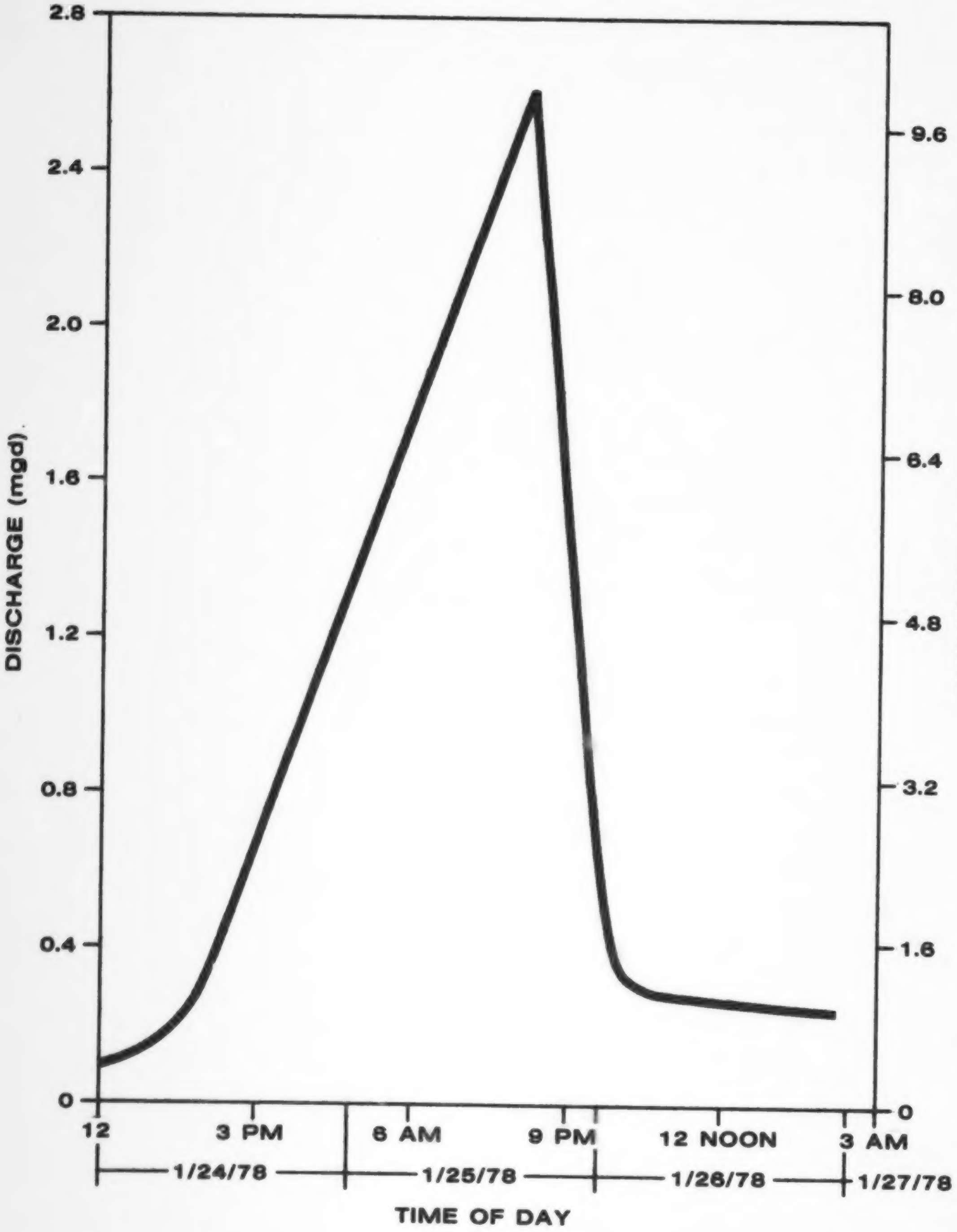


Figure D-2. Intensive site WV-07-SA runoff hydrograph - January 24-27, 1978.

APPENDIX E
WATER QUALITY DATA
INTENSIVE SITE WV-07-SA

TABLE E-1. WATER QUALITY DATA FROM WEEKLY COMPOSITE SAMPLES COLLECTED UPSTREAM OF THE SEDIMENTATION POND AT INTENSIVE SITE WV-07-SA DURING THE PRE-MINING PERIOD

Week	pH	Total alkalinity (mg/l $CaCO_3$)	Hot acidity (mg/l $CaCO_3$)	Turbidity (JTU)	Total solids (mg/l)	Total iron (mg/l)	Sulfate (mg/l)
1976							
12/14-20	5.7	16	26	190	1780	2.6	20
12/21-27	5.8	16	26	60	550	0.9	17
12/28-1/3	5.9	16	30	55	400	0.6	17
1977							
1/4-10	N/A	N/A	N/A	N/A	480	1.0	2
3/1-3	7.1	20	-10	4	65	0.1	N/A
3/7-12	6.6	18	- 8	20	182	0.1	22
3/13-9	6.8	19	- 2	75	89	0.0	25
3/21-27	7.1	22	2	80	115	0.1	28
4/7-13	7.2	25	-26	195	201	0.2	27
4/14-20	7.1	32	-44	2200	936	2.0	37
4/21-27	6.9	40	-86	4250	2355	5.7	33
4/28-30	6.8	29	-30	160	942	7.6	38
5/1-7	6.8	29	-16	60	340	2.0	18
5/8-14	6.8	30	-16	80	490	3.3	21
5/15-21	6.8	38	48	440	1520	19.0	25
5/22-28	6.7	46	82	600	2090	28.0	30

(continued)

TABLE E-1. (continued)

Week	pH	Total alkalinity (mg/l $CaCO_3$)	Hot acidity (mg/l $CaCO_3$)	Turbidity (JTU)	Total solids (mg/l)	Total iron (mg/l)	Sulfate (mg/l)
5/29-6/5	6.9	40	28	240	1320	1.2	25
6/6-12	7.1	38	22	140	813	1.8	20
6/13-19	6.6	42	0	250	2940	11.0	50
6/20-26	7.2	40	18	80	932	1.7	30
6/27-7/3	7.2	32	29	40	560	0.9	35
7/4-10	7.0	36	24	45	347	1.4	35
7/16-23	7.2	32	114	160	1080	1.5	35
8/2-8	7.2	32	-26	105	504	3.2	25
8/9-15	7.1	30	-22	95	493	2.8	27
8/16-21	6.7	20	-14	50	153	1.0	25
8/22-27	6.9	26	-18	80	490	1.1	25
9/2-9	6.7	42	-32	6	172	0.1	120
9/10-16	6.7	54	-48	15	160	1.5	24
9/17-22	4.8	11	18	300	2250	6.5	298
10/10-14	7.2	28	18	580	619	2.1	27
10/15-19	7.0	26	22	600	1620	4.5	25
10/20-23	6.8	22	- 8	70	244	3.7	28
11/7-11	6.8	20	-10	5	70	0.2	22
11/12-18	6.8	20	- 8	18	179	1.7	24
11/19-25	6.8	20	24	8	78	0.1	19

(continued)

TABLE E-1. (continued)

Week	pH	Total alkalinity (mg/l $CaCO_3$)	Hot acidity (mg/l $CaCO_3$)	Turbidity (JTU)	Total solids (mg/l)	Total iron (mg/l)	Sulfate (mg/l)
11/26-29	6.5	18	28	12	109	0.4	15
12/3-8	6.5	16	28	14	91	0.4	15
12/11-14	6.7	18	28	5	73	0.1	21
12/15-22	6.9	20	-8	3	75	0.2	25
12/23-25	6.9	20	-6	9	90	0.3	27
1978							
4/27-5/3	6.2	16	-84	100	326	4.5	25

TABLE E-2. WATER QUALITY DATA FROM WEEKLY COMPOSITE SAMPLES COLLECTED UPSTREAM OF THE SEDIMENTATION POND AT INTENSIVE SITE WV-07-SA DURING THE ACTIVE MINING PERIOD

week	pH	Total alkalinity (mg/l $CaCO_3$)	Hot acidity (mg/l $CaCO_3$)	Turbidity (JTU)	Total solids (mg/l)	Total iron (mg/l)	Sulfate (mg/l)
1978							
5/4-9	6.9	20	-82	46	208	2.0	24
5/10-16	6.5	24	- 8	22	46	0.5	25
5/17-24	6.1	32	-22	4	22	0.0	27
6/2-9	6.7	30	-14	82	174	1.5	35
6/10-17	6.5	34	-18	70	170	0.5	25
9/11-17	N/A	N/A	N/A	142	1736	18.1	1000
9/19-25	7.3	71	-64	900	3360	4.6	33
11/5-11	N/A	N/A	N/A	260	4076	29.9	32
11/12-18	N/A	N/A	N/A	261	4184	26.5	22
11/25-30	N/A	N/A	N/A	>1000	1350	8.7	20
12/1-5	N/A	N/A	N/A	99	304	2.8	54
12/6-10	N/A	N/A	N/A	350	4040	29.9	13
12/11-17	N/A	N/A	N/A	800	2670	19.3	14
1979							
6/9-15	4.5	13	41	4079	3298	29.4	35
6/16-21	6.4	37	16	94	6219	50.4	49

TABLE E-3. WATER QUALITY DATA FROM WEEKLY GRAB SAMPLES COLLECTED AT THE EFFLUENT OF THE SEDIMENTATION POND AT INTENSIVE SITE WV-07-SA DURING THE ACTIVE MINING PERIOD

Week	Turbidity (JTU)	Suspended solids (mg/l)	Week	Turbidity (JTU)	Suspended solids (mg/l)
1978			1979		
7/21-22	740	3252	1/2-7	170	N/A
8/8-10	440	668	1/15-21	80	N/A
8/22-24	50	32	3/1-7	140	N/A
8/29-9/1	870	3040	3/8-11	4	N/A
9/6-8	38	43	3/11-17	4	N/A
9/11-15	180	338	3/22-27	190	N/A
9/18-24	50	N/A	3/28-31	1	N/A
9/25-30	150	N/A	5/13-19	3	N/A
10/1-6	60	N/A	5/16-22	4	N/A
10/16-23	40	N/A	5/23-28	2	N/A
10/24-29	3	N/A	5/29-31	300	N/A
11/1-5	1	N/A	6/6-13	3	N/A
11/6-12	1	N/A	6/21-26	70	104
11/13-19	1	N/A	6/27-30	4	13
11/20-27	1	N/A			
11/28-12/1	3	N/A			
12/11-17	6	N/A			
12/18-23	10	N/A			
12/27-31	110	N/A			

TABLE E-4. WATER QUALITY DATA FROM MONTHLY COMPOSITE SAMPLES COLLECTED UPSTREAM OF THE SEDIMENTATION POND AT INTENSIVE SITE WV-07-SA DURING THE PRE-MINING PERIOD

	1976		1977		
	September	December	March	April	May
pH	N/A	6.5	6.8	7.1	7.2
Total alkalinity (mg/l $CaCO_3$)	0	10	13	29	34
Hot acidity (mg/l $CaCO_3$)	160	0	22	42	42
Turbidity (JTU)	<5	<5	18	250	260
Total solids (mg/l)	1184	70	174	886	1110
Suspended solids (mg/l)	44	7	98	784	904
Conductivity (µmhos/cm)	1380	85	90	125	130
Sulfate (mg/l)	35	20	20	30	30
Calcium (mg/l)	17	7	10	19	24
Magnesium (mg/l)	7	4	5	7	7
Manganese (mg/l)	0.2	0.0	0.1	1.0	1.3
Total iron (mg/l)	1.1	0.0	0.2	3.0	3.6
Dissolved iron (mg/l)	0.4	0.0	0.0	0.0	0.0
Aluminum (mg/l)	0.6	<0.1	0.1	2.3	2.6
Copper (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc (mg/l)	0.37	0.02	0.04	0.04	0.03
Cadmium (mg/l)	<0.01	<0.01	0.03	<0.01	<0.01
Nickel (mg/l)	<0.03	<0.03	<0.03	<0.03	<0.03

(continued)

TABLE E-4. (continued)

	1977				
	June	July	August	September	October
pH	7.1	7.2	6.9	7.4	6.4
Total alkalinity (mg/l $CaCO_3$)	36	34	25	40	30
Hot acidity (mg/l $CaCO_3$)	6	-8	2	-26	22
Turbidity (JTU)	200	120	140	375	400
Total solids (mg/l)	1070	615	652	1370	195000
Suspended solids (mg/l)	974	558	582	1110	194000
Conductivity (μmhos/cm)	155	145	95	280	120
Sulfate (mg/l)	34	30	24	100	30
Calcium (mg/l)	18	14	11	18	14
Magnesium (mg/l)	8	7	5	13	6
Manganese (mg/l)	2.5	0.9	1.2	0.7	1.6
Total iron (mg/l)	5.1	2.9	2.7	3.8	12.6
Dissolved iron (mg/l)	0.1	0.0	0.0	0.0	0.2
Aluminum (mg/l)	3.1	1.4	1.7	3.0	8.5
Copper (mg/l)	<0.01	<0.01	<0.01	<0.01	0.02
Zinc (mg/l)	0.30	0.23	0.23	0.09	0.07
Cadmium (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel (mg/l)	<0.03	<0.03	<0.03	<0.03	<0.03

(continued)

TABLE E-4. (continued)

	1977 November	 December	1978 April
pH	6.7	6.6	6.8
Total alkalinity (mg/l $CaCO_3$)	128	22	28
Hot acidity (mg/l $CaCO_3$)	-26	-2	0
Turbidity (JTU)	>1000	16	140
Total solids (mg/l)	65500	174	489
Suspended solids (mg/l)	65100	43	394
Conductivity (µmhos/cm)	450	95	100
Sulfate (mg/l)	190	25	29
Calcium (mg/l)	110	10	7
Magnesium (mg/l)	99	4	5
Manganese (mg/l)	27.0	0.1	0.6
Total iron (mg/l)	55.6	1.3	5.2
Dissolved iron (mg/l)	0.1	0.0	0.0
Aluminum (mg/l)	22.5	0.7	4.9
Copper (mg/l)	0.78	0.01	0.01
Zinc (mg/l)	2.40	0.03	0.03
Cadmium (mg/l)	0.01	<0.01	<0.01
Nickel (mg/l)	0.98	<0.03	0.03

TABLE E-5. WATER QUALITY DATA FROM MONTHLY COMPOSITE SAMPLES COLLECTED UPSTREAM OF THE SEDIMENTATION POND AT INTENSIVE SITE WV-07-SA DURING THE ACTIVE MINING PERIOD

	1978				1979	
	May	September	November	December	March	June
pH	6.6	N/A	N/A	N/A	N/A	5.9
Total alkalinity (mg/l $CaCO_3$)	22	N/A	N/A	N/A	N/A	110
Hot acidity (mg/l $CaCO_3$)	-6	N/A	N/A	N/A	N/A	5
Turbidity (JTU)	48	730	964	410	290	260
Total solids (mg/l)	180	3264	836	3760	5434	6363
Suspended solids (mg/l)	96	N/A	N/A	N/A	N/A	6192
Conductivity (µmhos/cm)	80	1740	159	127	147	240
Sulfate (mg/l)	24	1010	26	15	16	52
Calcium (mg/l)	4	158	16	10	23	16
Magnesium (mg/l)	4	108	7	5	7	15.5
Manganese (mg/l)	0.2	7.9	0.5	1.6	2.8	3.5
Total iron (mg/l)	1.6	29.4	5.2	18.4	19.6	25.2
Dissolved iron (mg/l)	<0.01	N/A	N/A	N/A	N/A	N/A
Aluminum (mg/l)	1.6	18.6	4.0	18.9	16.5	14.0
Copper (mg/l)	0.01	0.04	0.03	0.06	0.07	0.06
Zinc (mg/l)	0.03	0.66	0.09	0.17	0.19	0.14
Cadmium (mg/l)	<0.01	<0.01	0.01	0.03	<0.01	<0.01
Nickel (mg/l)	<0.03	0.39	0.03	0.07	0.08	0.07

TABLE E-6. WATER QUALITY DATA FROM MONTHLY COMPOSITE SAMPLES COLLECTED AT THE EFFLUENT OF THE SEDIMENTATION POND AT INTENSIVE SITE WV-07-SA DURING THE ACTIVE MINING PERIOD

	1978			
	September	October	November	December
Turbidity (JTU)	100	0	1	20
Total solids (mg/l)	2042	1818	896	228
Conductivity (µmhos/cm)	1842	1789	959	195
Sulfate (mg/l)	1200	1200	590	74
Calcium (mg/l)	165	169	89	11
Magnesium (mg/l)	118	116	59	9
Manganese (mg/l)	13.2	7.5	4.6	0.1
Total iron (mg/l)	8.6	0.4	0.1	0.9
Aluminum (mg/l)	10.7	14.4	1.9	0.5
Copper (mg/l)	0.04	0.04	0.01	0.01
Zinc (mg/l)	0.73	0.66	0.22	0.02
Cadmium (mg/l)	<0.01	<0.01	<0.01	<0.01
Nickel (mg/l)	0.39	0.43	0.16	<0.03

(continued)

TABLE E-6. (continued)

	1979 January	March	April	May
Turbidity (JTU)	100	44	40	130
Total solids (mg/l)	372	222	130	334
Conductivity (µmhos/cm)	150	159	145	190
Sulfate (mg/l)	46	51	47	56
Calcium (mg/l)	14	21	14	15
Magnesium (mg/l)	8	8	7	9
Manganese (mg/l)	0.5	0.1	0.1	0.2
Total iron (mg/l)	2.8	0.8	0.3	1.3
Aluminum (mg/l)	1.4	0.5	<0.1	1.1
Copper (mg/l)	0.02	0.01	<0.01	0.01
Zinc (mg/l)	0.03	0.02	<0.01	0.03
Cadmium (mg/l)	<0.01	<0.01	<0.01	<0.01
Nickel (mg/l)	<0.03	<0.03	<0.03	<0.03

APPENDIX F
WOODY VEGETATION DATA
INTENSIVE SITE WV-07-SA

TABLE F-1. TREE SPECIES DATA COLLECTED THROUGH RANDOM PAIRS SAMPLING AT INTENSIVE SITE WV-07-SA

Transect no.	Point No.	Point Pairs	Species	Tree diameter (cm)	Tree diameter (in)	Distance A to B (m)	Distance A to B (ft)
T-1 (end of ridge has been burned)	1	A	black gum	11.4	4.5	3.6	12.0
		B	black locust	20.3	8.0		
	2	A	scarlet oak	28.7	11.3	5.4	17.9
		B	chestnut oak	86.1	33.9		
	3	A	pitch pine	41.7	16.4	8.5	27.9
		B	chestnut oak	67.1	26.4		
	4	A	chestnut oak	33.5	13.2	16.8	55.1
		B	chestnut oak	37.1	14.6		
T-2 (followed ridge line which will be removed during mining)	1	A	black oak	49.3	19.4	13.1	43.0
		B	chestnut oak	60.7	23.9		
	2	A	bitternut hickory	35.3	13.9	13.7	45.2
		B	yellow-poplar	28.7	11.3		
	3	A	black gum	39.4	15.5	9.1	30.0
		B	oak (unidentified sp.)	17.8	7.0		
	4	A	scarlet oak	21.3	8.4	5.5	18.0
		B	scarlet oak	23.4	9.2		
	5	A	sassafras	15.5	6.1	8.2	27.0
		B	white oak	28.7	11.3		
	6	A	chestnut oak	31.8	12.5	3.3	10.9
		B	shagbark hickory	18.0	7.1		
	7	A	chestnut oak	42.9	16.9	7.1	23.2
		B	pignut hickory	36.1	14.2		
	8	A	chokecherry	13.0	5.1	9.2	30.3
		B	pignut hickory	34.3	13.5		
	9	A	chestnut oak	43.4	17.1	9.4	31.0
		B	chestnut oak	102.9	40.5		
	10	A	no data under power line				
		B					
	11	A	chestnut oak	51.6	20.3	10.5	34.5
		B	chestnut oak	35.6	14.0		

(continued)

TABLE F-1. (continued)

Transect no.	Point No.	Pairs	Species	Tree diameter (cm)	Tree diameter (in)	Distance A to B (m)	Distance A to B (ft)
T-2 (Cont'd.)	12	A	scarlet oak	31.5	12.4	7.0	23.0
		B	chestnut oak	15.0	5.9		
	13	A	pitch pine	16.8	6.6	6.1	20.0
		B	chestnut oak	58.4	23.0		
T-3 (upper slope of hollow to be filled near coal outcrop)	1	A	chokecherry	16.3	6.4	2.8	9.3
		B	chestnut oak	30.7	12.1		
	2	A	shagbark hickory	16.5	6.5	4.3	14.0
		B	pignut hickory	21.1	8.3		
	3	A	yellow-poplar	32.8	12.9	8.4	27.5
		B	chokecherry	19.8	7.8		
	4	A	chestnut oak	13.0	5.1	2.4	8.0
		B	red maple	13.0	5.1		
	5	A	chestnut oak	20.6	8.1	4.1	13.4
		B	chestnut oak	28.4	11.2		
	6	A	scarlet oak	27.7	10.9	9.7	32.0
		B	chokecherry	43.7	17.2		
	7	A	chestnut oak	18.0	7.1	4.3	14.0
		B	chestnut oak	20.8	8.2		
	8	A	chokecherry	21.3	8.4	6.2	20.5
		B	pignut hickory	22.6	8.9		
	9	A	shagbark hickory	22.9	9.0	1.6	5.1
		B	black gum	32.0	12.6		
	10	A	pignut hickory	21.1	8.3	8.2	27.0
		B	yellow-poplar	22.9	9.0		
	11	A	yellow-poplar	23.4	9.2	6.1	20.0
		B	basswood	15.2	6.0		
	12	A	flowering dogwood	15.5	6.1	7.6	25.0
		B	shagbark hickory	24.1	9.5		
	13	A	flowering dogwood	13.0	5.1	2.2	7.3
		B	flowering dogwood	14.2	5.6		

(continued)

TABLE F-1. (continued)

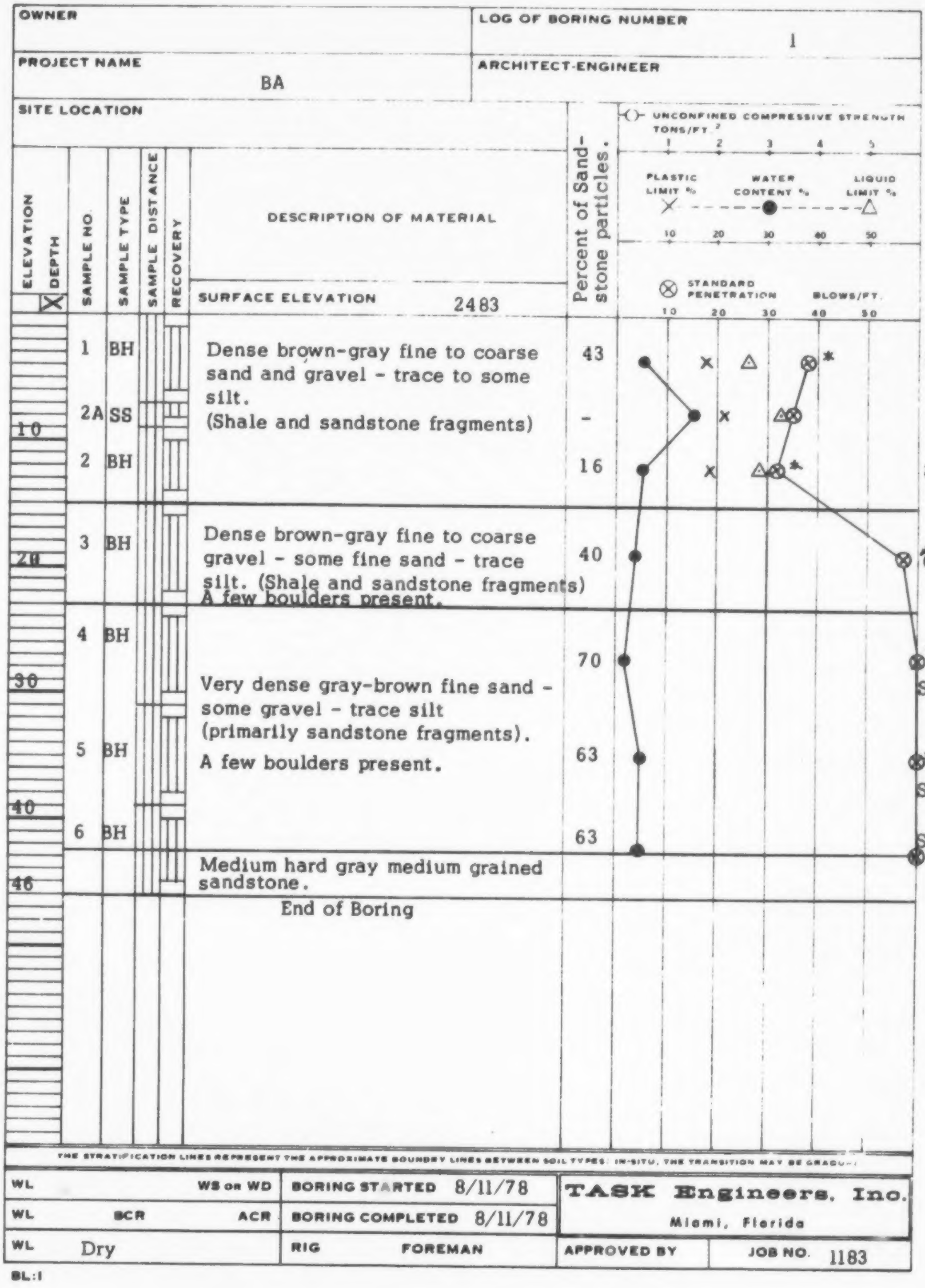
Transect no.	Point No.	Point Pairs	Species	Tree diameter (cm)	Tree diameter (in)	Distance A to B (m)	Distance A to B (ft)
T-3 (Cont'd.)	14	A	chestnut oak	61.7	24.3	9.7	31.9
		B	pignut hickory	43.9	17.3		
	15	A	chokecherry	17.5	6.9	3.8	12.6
		B	red maple	16.8	6.6		
	16	A	chokecherry	10.9	4.3	1.9	6.2
		B	scarlet oak	32.5	12.8		
	17	A	chestnut oak	45.2	17.8	7.3	24.0
		B	scarlet oak	58.4	23.0		
T-4 (head-of-hollow right side, 200 ft. below coal outcrop)	1	A	black gum	25.9	10.2	4.0	13.0
		B	chestnut oak	17.5	6.9		
	2	A	flowering dogwood	22.9	9.0	5.2	17.0
		B	black gum	20.6	8.1		
	3	A	bitternut hickory	30.7	12.1	2.7	9.0
		B	black gum	21.6	8.5		
	4	A	flowering dogwood	14.5	5.7	7.1	23.5
		B	red maple	10.9	4.3		
	5	A	black oak	72.9	28.7	7.0	23.0
		B	sassafras	16.5	6.5		
	6	A	black gum	25.4	10.0	7.1	23.4
		B	black gum	39.9	15.7		
	7	A	basswood	28.4	11.2	8.2	27.0
		B	black gum	39.4	15.5		
	8	A	basswood	11.9	4.7	6.7	22.0
		B	basswood	30.0	11.8		
	9	A	basswood	39.9	15.7	6.7	22.0
		B	black oak	16.8	6.6		
	10	A	chestnut oak	11.9	4.7	2.0	6.5
		B	chestnut oak	14.5	5.7		
	11	A	black gum	17.5	6.9	3.2	10.5
		B	basswood	29.2	11.5		

(continued)

TABLE F-1. (continued)

Transect no.	Point No.	Point Pairs	Species	Tree diameter (cm)	Tree diameter (in)	Distance A to B (m)	Distance A to B (ft)
T-4 (Cont'd.)	12	A	yellow-poplar	12.4	4.9	7.9	25.9
		B	black gum	15.2	6.0		
	13	A	yellow-poplar	16.0	6.3	9.9	32.5
		B	sassafras	10.2	4.0		
T-5 (left side of hollow, 200 ft. below coal outcrop)	1	A	pignut hickory	18.0	7.1	4.3	14.0
		B	black gum	20.6	8.1		
	2	A	black locust	11.2	4.4	4.2	13.8
		B	red maple	12.4	4.9		
	3	A	red maple	10.2	4.0	5.6	18.5
		B	chestnut oak	68.1	26.8		
	4	A	black gum	10.4	4.1	14.0	46.0
		B	chestnut oak	73.2	28.8		

APPENDIX G
HEAD-OF-HOLLOW FILL SUBSURFACE INVESTIGATION DATA



OWNER

LOG OF BORING NUMBER 1

PROJECT NAME BA

ARCHITECT-ENGINEER

SITE LOCATION

SURFACE ELEVATION 2483

ELEVATION ☒ DEPTH	SAMPLE NO.	SAMPLE TYPE	DESCRIPTION OF MATERIAL	Percent of Sand-stone particles.	
	1	BH	Dense brown-gray fine to coarse sand and gravel - trace to some silt. (Shale and sandstone fragments)	43	SC
10	2A	SS		-	
	2	BH		16	SP
20	3	BH	Dense brown-gray fine to coarse gravel - some fine sand - trace silt. (Shale and sandstone fragments) A few boulders present.	40	GP-GM
	4	BH	Very dense gray-brown fine sand - some gravel - trace silt (primarily sandstone fragments). A few boulders present.	70	72 SP-SM
30					
	5	BH		63	103 SP-SM
40					
	6	BH		63	SW-SM 135
46			Medium hard gray medium grained sandstone.		
			End of Boring		

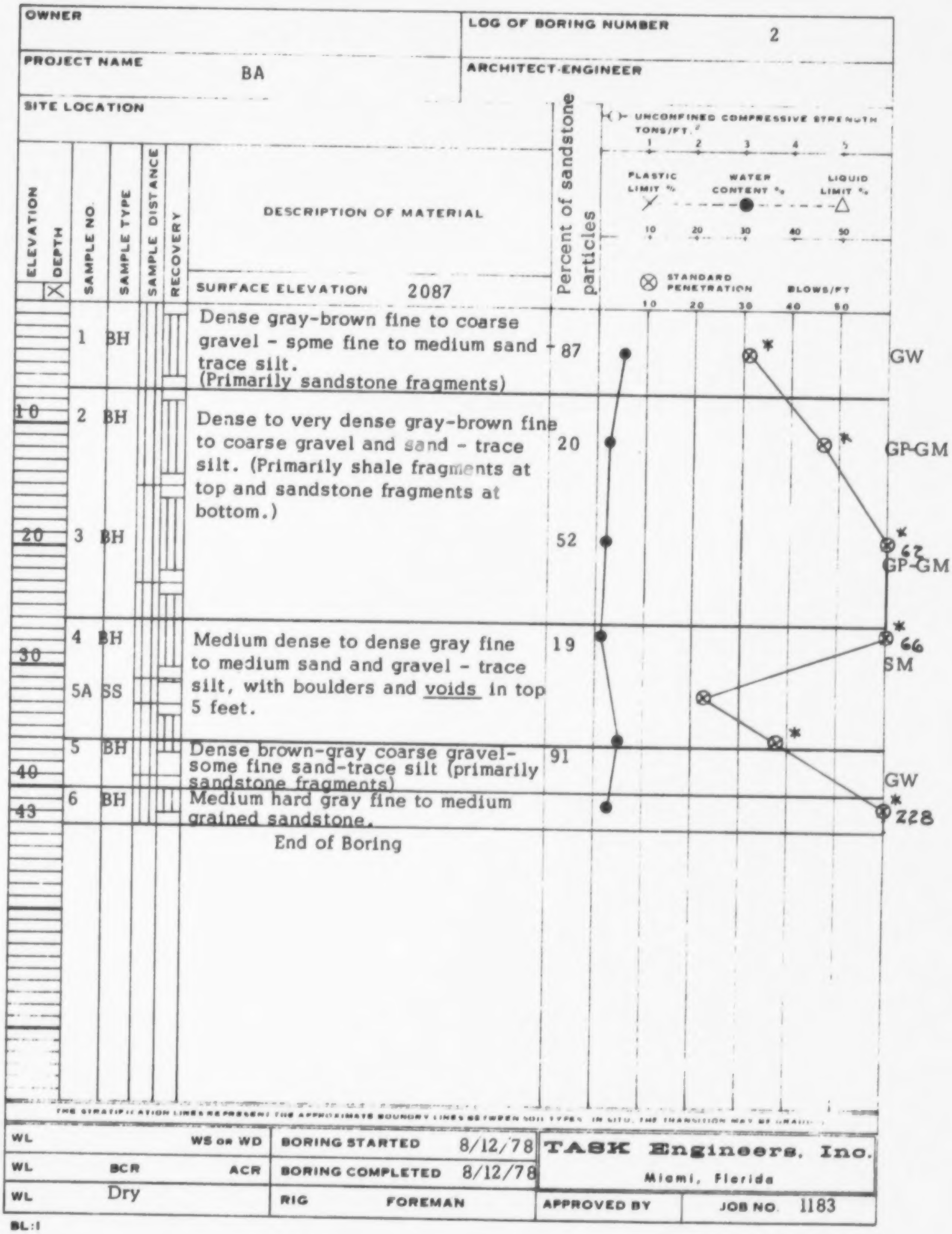
SAMPLE DISTANCE
RECOVERY
-()- UNCONFINED COMPRESSIVE STRENGTH TONS/FT.²
1
2
3
4
5
PLASTIC LIMIT %
WATER CONTENT %
LIQUID LIMIT %
10
20
30
40
50
⊗ STANDARD PENETRATION BLOWS/FT.
10
20
30
40
50
*

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDRY LINES BETWEEN SOIL TYPES: IN-SITU, THE TRANSITION MAY BE GRADU-

WL WS or WD	BORING STARTED 8/11/78	TASK Engineers, Inc. Miami, Florida
WL BCR ACR	BORING COMPLETED 8/11/78	
WL Dry	RIG FOREMAN	APPROVED BY JOB NO. 1183

BL:1

Figure G-1. Boring log - Hole # BA-1.



OWNER	LOG OF BORING NUMBER 2
PROJECT NAME BA	ARCHITECT-ENGINEER
SITE LOCATION	

SURFACE ELEVATION 2087

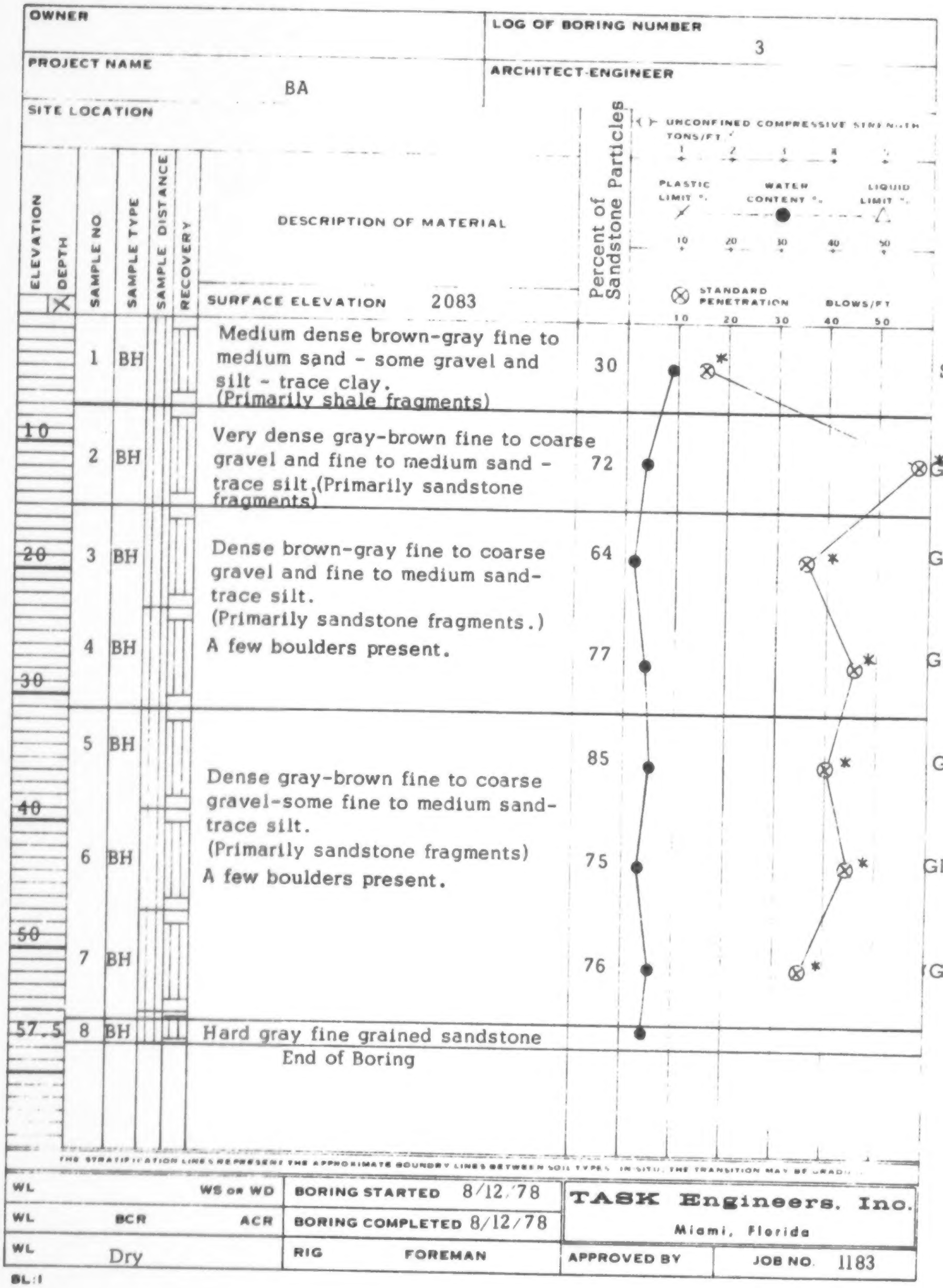
ELEVATION / DEPTH	SAMPLE NO.	SAMPLE TYPE	DESCRIPTION OF MATERIAL	Percent of sandstone particles	
	1	BH	Dense gray-brown fine to coarse gravel - some fine to medium sand - trace silt. (Primarily sandstone fragments)	87	GW
10	2	BH	Dense to very dense gray-brown fine to coarse gravel and sand - trace silt. (Primarily shale fragments at top and sandstone fragments at bottom.)	20	GP-GM
20	3	BH		52	GP-GM
30	4	BH	Medium dense to dense gray fine to medium sand and gravel - trace silt, with boulders and voids in top 5 feet.	19	SM
	5A	SS			
	5	BH	Dense brown-gray coarse gravel-some fine sand-trace silt (primarily sandstone fragments)	91	GW
40 / 43	6	BH	Medium hard gray fine to medium grained sandstone.		
			End of Boring		

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES. IN SITU, THE TRANSITION MAY BE GRADUAL.

WL WS or WD	BORING STARTED 8/12/78	TASK Engineers, Inc. Miami, Florida
WL BCR ACR	BORING COMPLETED 8/12/78	
WL Dry	RIG FOREMAN	APPROVED BY / JOB NO. 1183

BL:1

Figure G-2. Boring log - Hole # BA-2.



OWNER	LOG OF BORING NUMBER 3
PROJECT NAME BA	ARCHITECT-ENGINEER
SITE LOCATION	

DESCRIPTION OF MATERIAL

SURFACE ELEVATION 2083

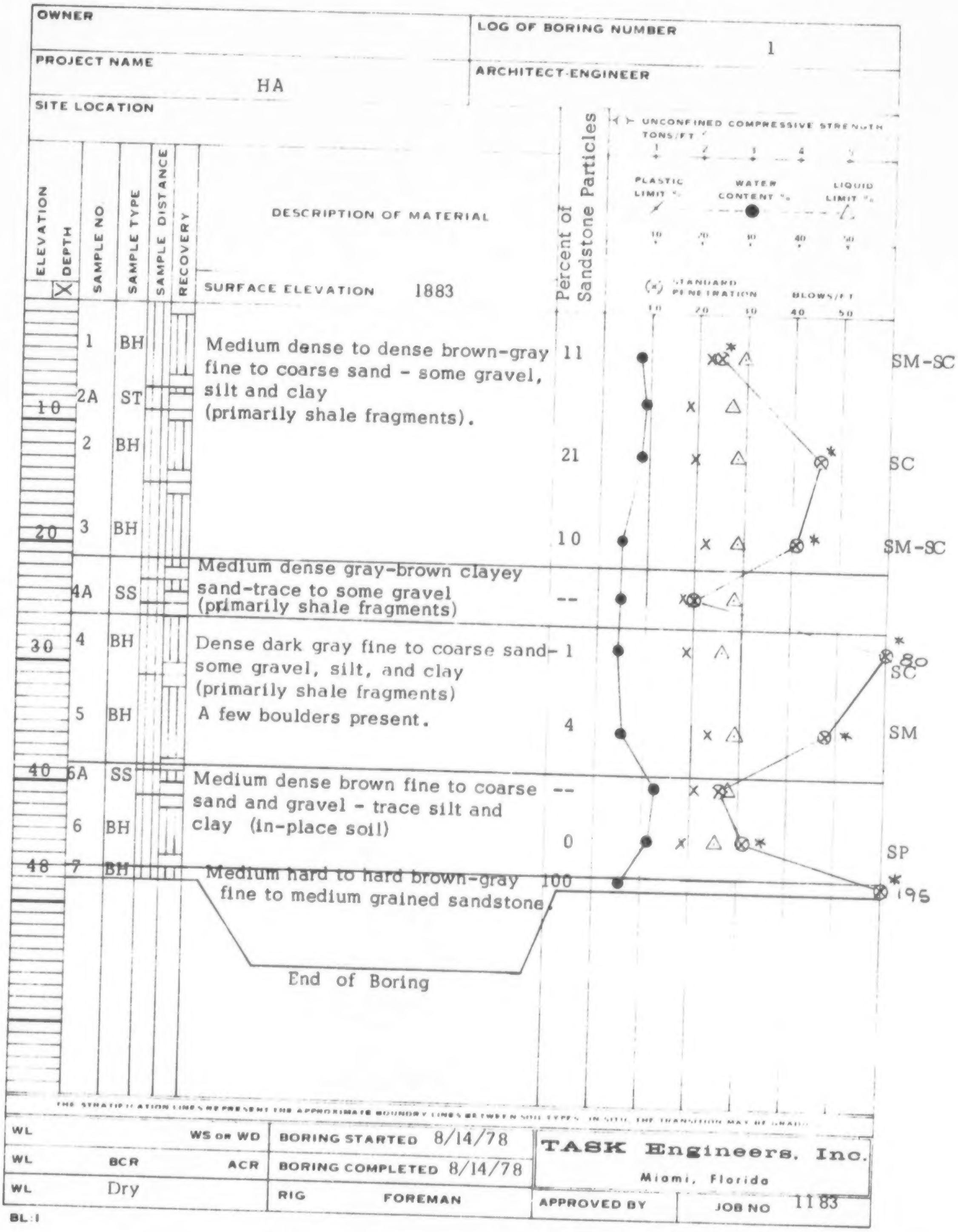
DEPTH	SAMPLE NO	SAMPLE TYPE	DESCRIPTION OF MATERIAL	Percent of Sandstone Particles	
	1	BH	Medium dense brown-gray fine to medium sand - some gravel and silt - trace clay. (Primarily shale fragments)	30	SC
10	2	BH	Very dense gray-brown fine to coarse gravel and fine to medium sand - trace silt.(Primarily sandstone fragments)	72	GP-GM
20	3	BH	Dense brown-gray fine to coarse gravel and fine to medium sand- trace silt. (Primarily sandstone fragments.) A few boulders present.	64	GP-GM
30	4	BH		77	GP-GM
	5	BH	Dense gray-brown fine to coarse gravel-some fine to medium sand- trace silt. (Primarily sandstone fragments) A few boulders present.	85	GP
40	6	BH		75	GP-GM
50	7	BH		76	GW
57.5	8	BH	Hard gray fine grained sandstone		
			End of Boring		

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDRY LINES BETWEEN SOIL TYPES. IN SITU, THE TRANSITION MAY BE GRADU

WL WS OR WD	BORING STARTED 8/12/78	TASK Engineers, Inc. Miami, Florida
WL BCR ACR	BORING COMPLETED 8/12/78	
WL Dry	RIG FOREMAN	APPROVED BY / JOB NO. 1183

BL:I

Figure G-3. Boring log - Hole # BA-3.



OWNER	
LOG OF BORING NUMBER	1
PROJECT NAME	HA
ARCHITECT-ENGINEER	
SITE LOCATION	
SURFACE ELEVATION	1883

ELEVATION / DEPTH	SAMPLE NO	SAMPLE TYPE	SAMPLE DISTANCE	RECOVERY	DESCRIPTION OF MATERIAL	Percent of Sandstone Particles	
	1	BH			Medium dense to dense brown-gray fine to coarse sand - some gravel, silt and clay (primarily shale fragments).	11	SM-SC
10	2A	ST					
	2	BH				21	SC
20	3	BH				10	SM-SC
	4A	SS			Medium dense gray-brown clayey sand-trace to some gravel (primarily shale fragments)	--	
30	4	BH			Dense dark gray fine to coarse sand-some gravel, silt, and clay (primarily shale fragments) A few boulders present.	1	SC
	5	BH				4	SM
40	6A	SS			Medium dense brown fine to coarse sand and gravel - trace silt and clay (in-place soil)	--	
	6	BH				0	SP
48	7	BH			Medium hard to hard brown-gray fine to medium grained sandstone.	100	

End of Boring

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES. IN SITU, THE TRANSITION MAY BE GRADUAL.

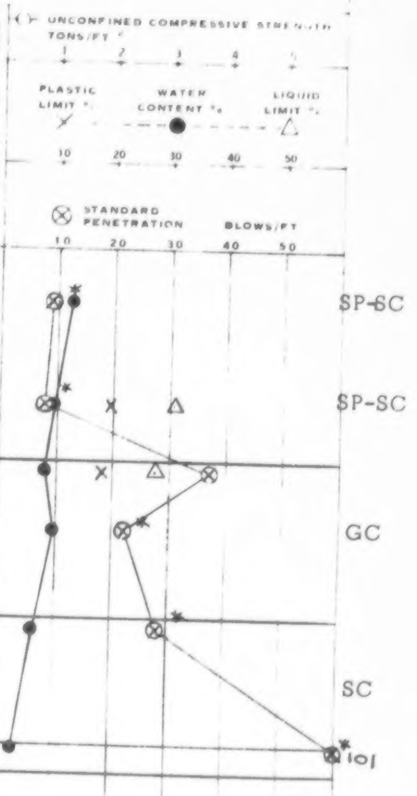
WL WS OR WD	BORING STARTED 8/14/78	TASK Engineers, Inc. Miami, Florida	
WL BCR ACR	BORING COMPLETED 8/14/78		
WL Dry	RIG FOREMAN	APPROVED BY	JOB NO 1183

BL:1

Figure G-4. Boring log - Hole # HA-1.

OWNER	LOG OF BORING NUMBER 2
PROJECT NAME HA	ARCHITECT ENGINEER
SITE LOCATION	

ELEVATION	DEPTH ☒	SAMPLE NO	SAMPLE TYPE	SAMPLE DISTANCE	RECOVERY	DESCRIPTION OF MATERIAL SURFACE ELEVATION + 1850	Percent of Sandstone Particles	
		1	BH			Loose gray brown fine to coarse sand - some gravel - trace silt and clay (primarily shale fragments) (voids at 10 ft. to 12 ft.) A few boulders present.	1	SP-SC
	10	2	BH				7	SP-SC
		3A	SS			Medium dense to dense gray fine fine to coarse gravel and sand - some silt and clay (shale fragments)		
	20	3	BH				0	GC
		4	BH			Medium dense brown-gray fine to coarse sand and gravel - some silt and clay (shale fragments).		
	30						0	SC
		5	BH					
	37					Hard brown-gray sandstone		
						End of Boring		

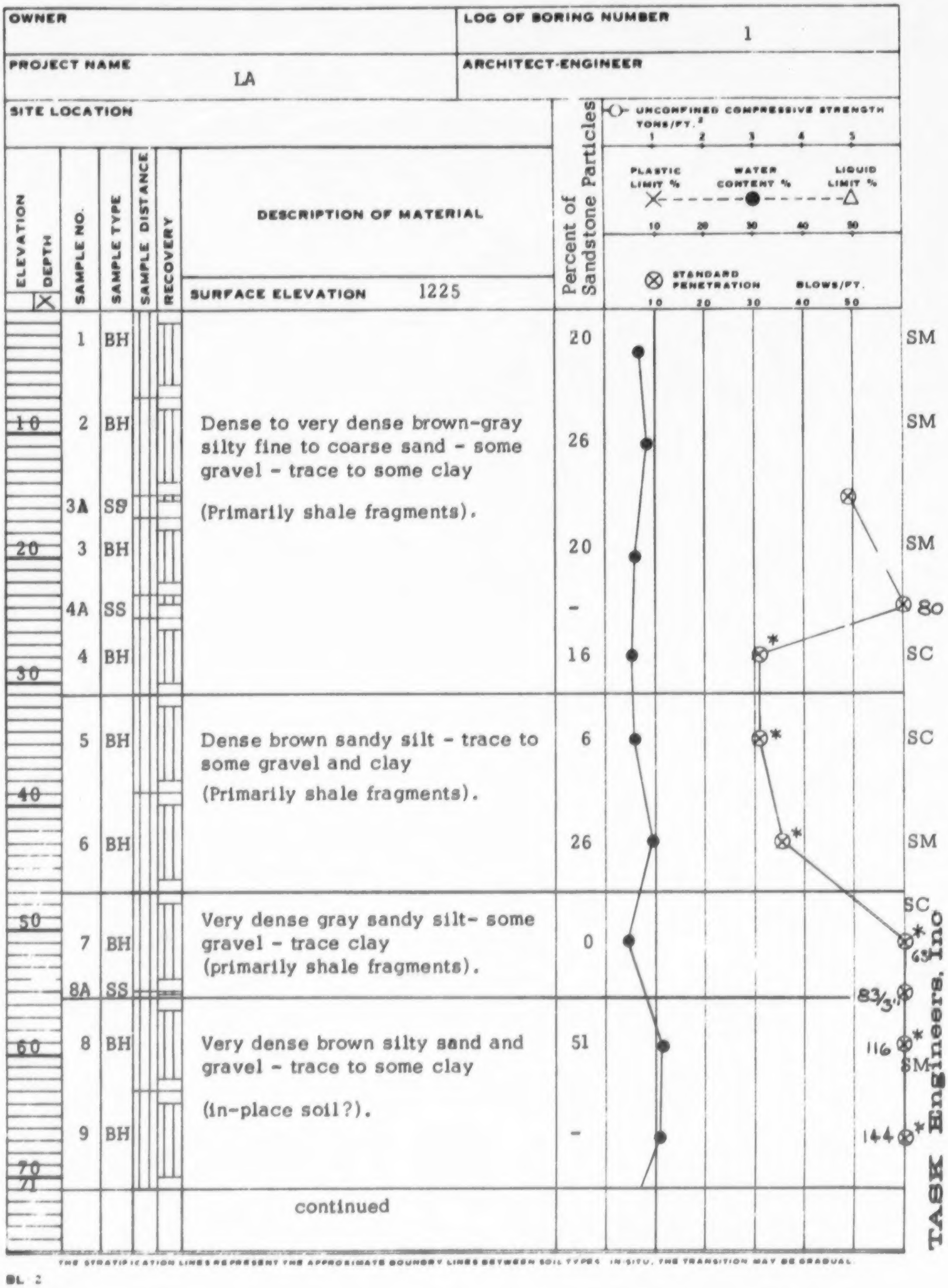


THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDRY LINES BETWEEN SOIL TYPES: IN-SITU, THE TRANSITION MAY BE GRAD...

WL	WS OR WD	BORING STARTED 8/14/78	**TASK Engineers, Inc.** Miami, Florida	
WL BCR	ACR	BORING COMPLETED 8/14/78		
WL Dry		RIG FOREMAN	APPROVED BY	JOB NO. 1183

BL:I

Figure G-5. Boring log - Hole # HA-2.



OWNER	LOG OF BORING NUMBER 1
PROJECT NAME LA	ARCHITECT-ENGINEER
SITE LOCATION	

SURFACE ELEVATION 1225

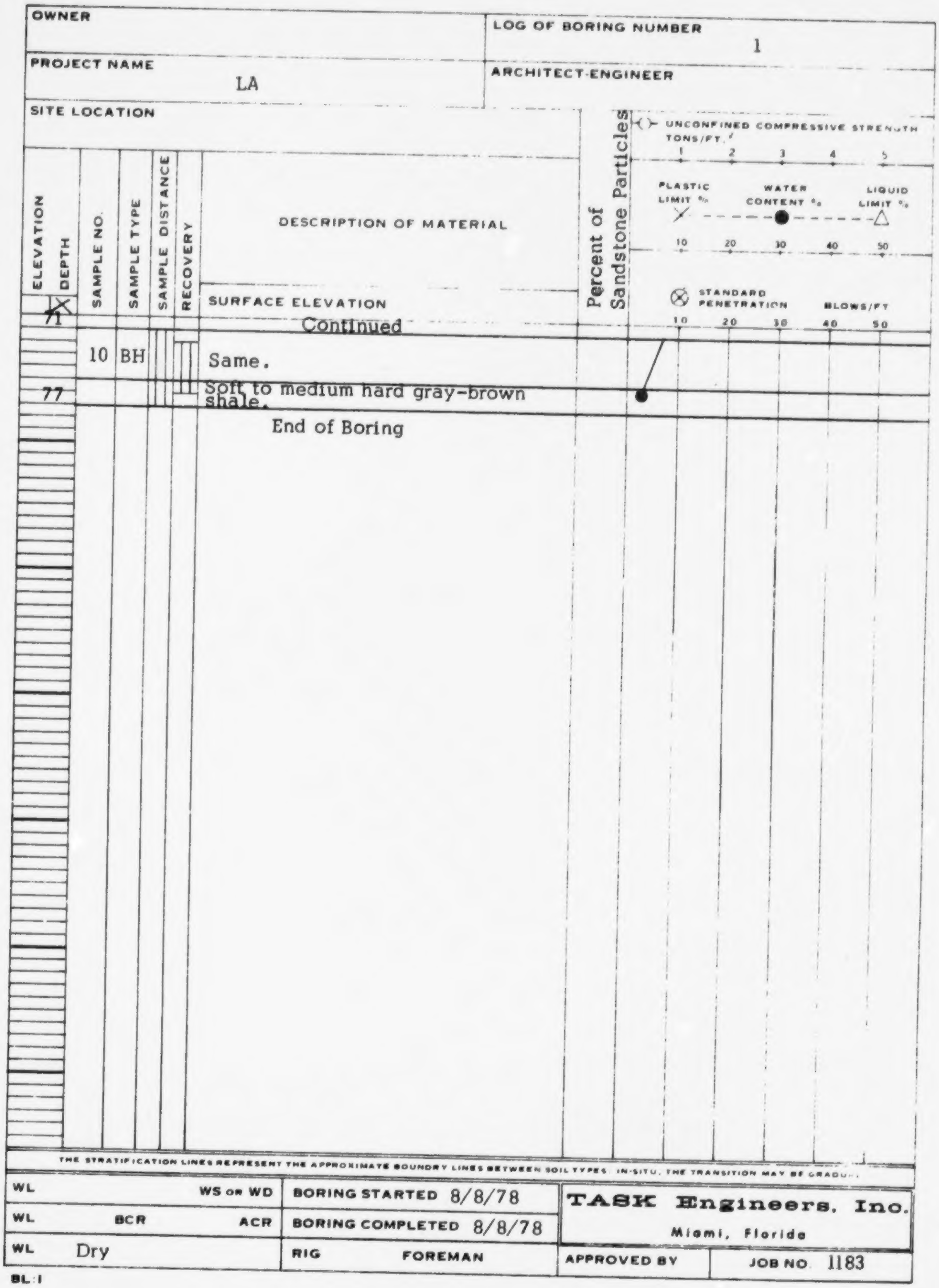
ELEVATION / DEPTH	SAMPLE NO.	SAMPLE TYPE	DESCRIPTION OF MATERIAL	Percent of Sandstone Particles	
	1	BH	Dense to very dense brown-gray silty fine to coarse sand - some gravel - trace to some clay (Primarily shale fragments).	20	SM
10	2	BH		26	SM
	3A	SS			
20	3	BH		20	SM
	4A	SS		-	
30	4	BH		16	SC
	5	BH	Dense brown sandy silt - trace to some gravel and clay (Primarily shale fragments).	6	SC
40	6	BH		26	SM
50	7	BH	Very dense gray sandy silt- some gravel - trace clay (primarily shale fragments).	0	SC
	8A	SS			
60	8	BH	Very dense brown silty sand and gravel - trace to some clay (in-place soil?).	51	SM
70 71	9	BH		-	
			continued		

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES IN-SITU, THE TRANSITION MAY BE GRADUAL.

BL 2

UNCONFINED COMPRESSIVE STRENGTH TONS/FT.²
1 2 3 4 5
PLASTIC LIMIT %
WATER CONTENT %
LIQUID LIMIT %
10 20 30 40 50
STANDARD PENETRATION
BLOWS/FT.
10 20 30 40 50
80
*
*
*
63*
83/3"
116*
144*
TASK Engineers, Inc

Figure G-6. Boring log - Hole # LA-1.



OWNER

LOG OF BORING NUMBER 1

PROJECT NAME LA

ARCHITECT-ENGINEER

SITE LOCATION

UNCONFINED COMPRESSIVE STRENGTH TONS/FT.² 1 2 3 4 5

PLASTIC LIMIT % ✕ - - - - WATER CONTENT % ● - - - - LIQUID LIMIT % △

10 20 30 40 50

⊗ STANDARD PENETRATION BLOWS/FT 10 20 30 40 50

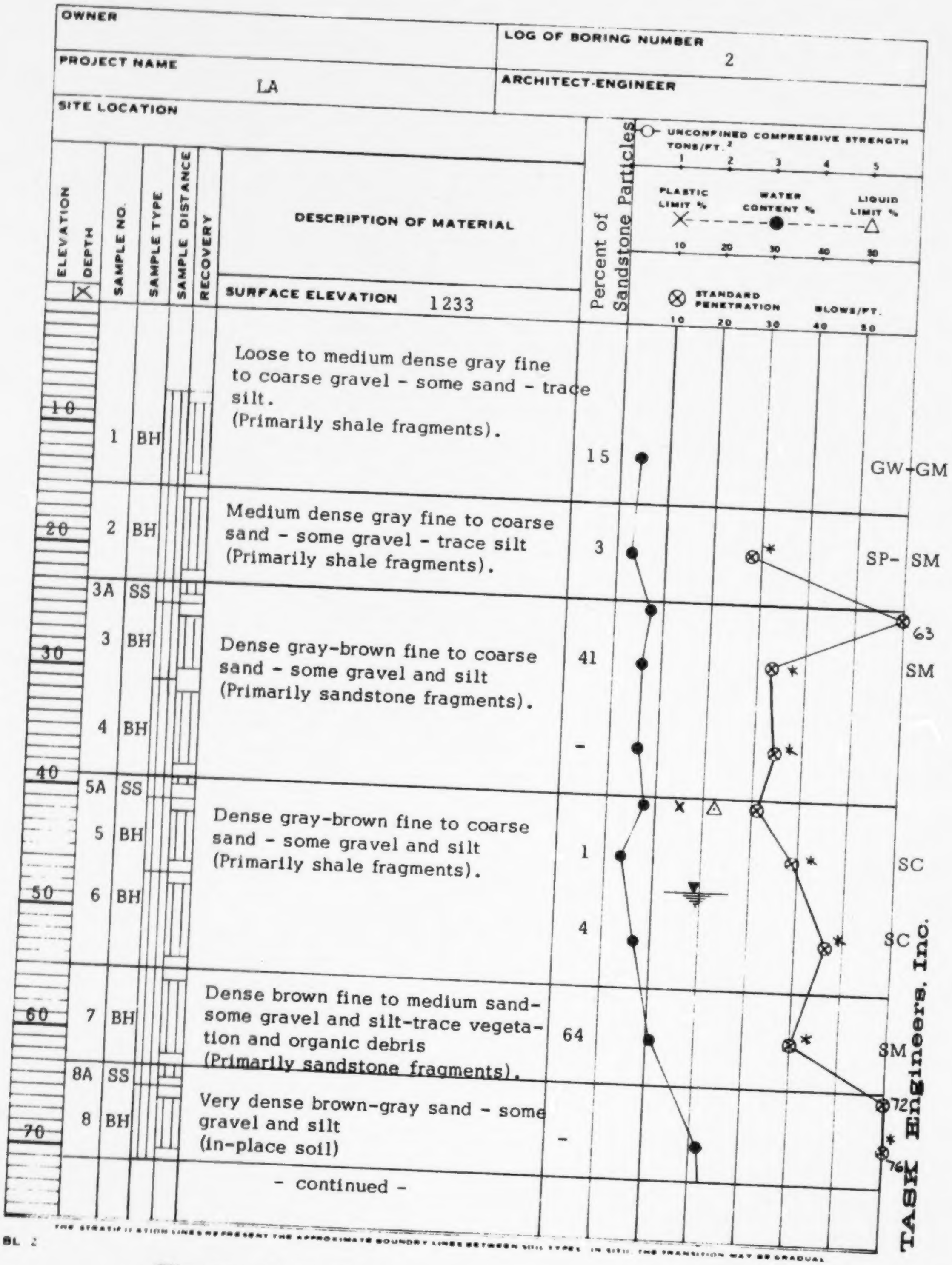
ELEVATION / DEPTH	SAMPLE NO.	SAMPLE TYPE	SAMPLE DISTANCE	RECOVERY	DESCRIPTION OF MATERIAL SURFACE ELEVATION	Percent of Sandstone Particles
71					Continued	
	10	BH			Same.	
77					Soft to medium hard gray-brown shale.	
					End of Boring	

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDRY LINES BETWEEN SOIL TYPES. IN-SITU, THE TRANSITION MAY BE GRADU

WL WS OR WD	BORING STARTED 8/8/78	**TASK Engineers, Inc.** Miami, Florida	
WL BCR ACR	BORING COMPLETED 8/8/78		
WL Dry	RIG FOREMAN	APPROVED BY	JOB NO. 1183

BL:I

Figure G-6 (continued). Boring log - Hole #LA-1.



OWNER

LOG OF BORING NUMBER 2

PROJECT NAME LA

ARCHITECT-ENGINEER

SITE LOCATION

SURFACE ELEVATION 1233

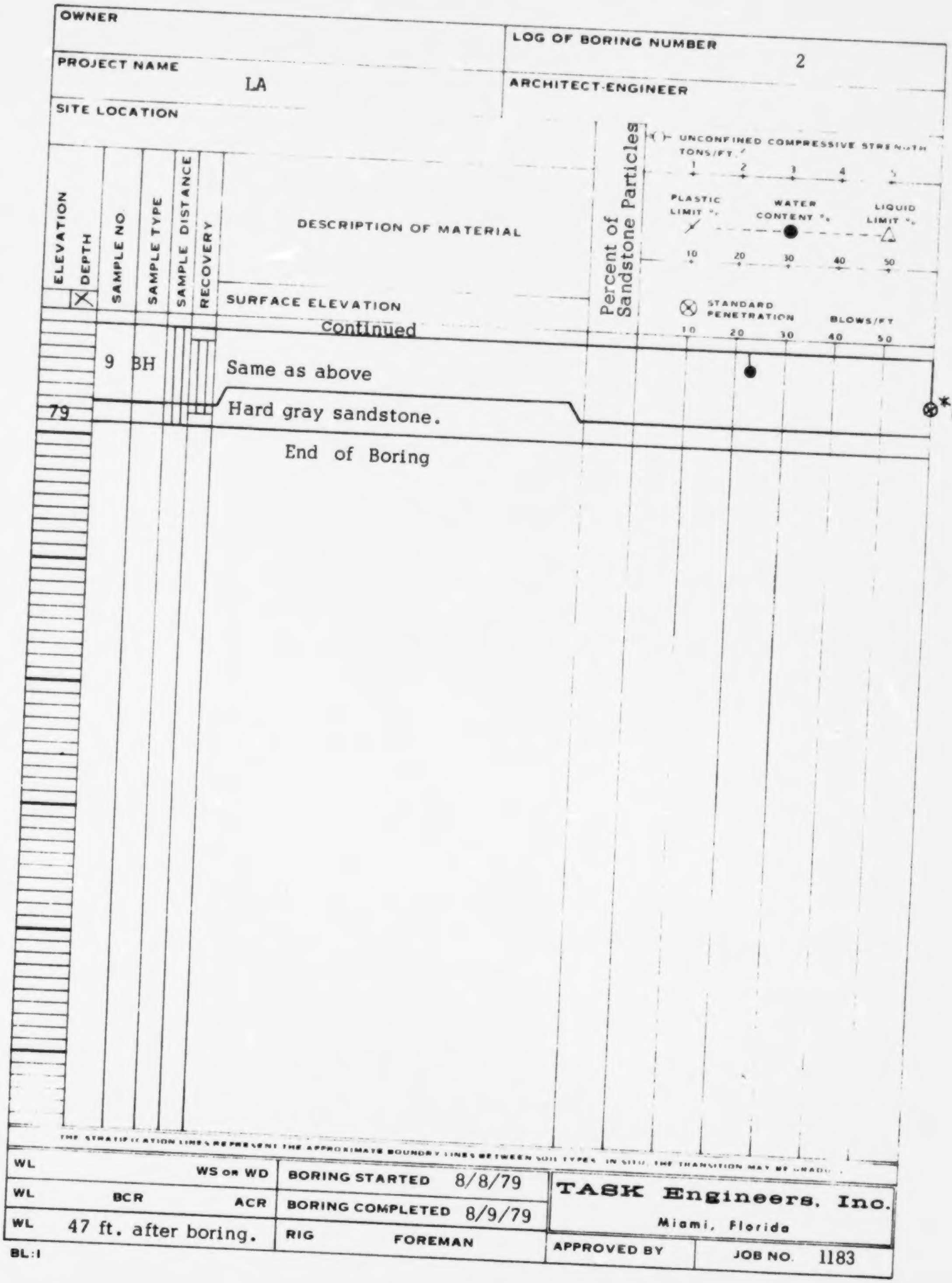
ELEVATION / DEPTH	SAMPLE NO.	SAMPLE TYPE	DESCRIPTION OF MATERIAL	Percent of Sandstone Particles	
10	1	BH	Loose to medium dense gray fine to coarse gravel - some sand - trace silt. (Primarily shale fragments).	15	GW-GM
20	2	BH	Medium dense gray fine to coarse sand - some gravel - trace silt (Primarily shale fragments).	3	SP- SM
	3A	SS			
30	3	BH	Dense gray-brown fine to coarse sand - some gravel and silt (Primarily sandstone fragments).	41	SM
	4	BH		-	
40	5A	SS			
	5	BH	Dense gray-brown fine to coarse sand - some gravel and silt (Primarily shale fragments).	1	SC
50	6	BH		4	SC
60	7	BH	Dense brown fine to medium sand-some gravel and silt-trace vegetation and organic debris (Primarily sandstone fragments).	64	SM
	8A	SS			
70	8	BH	Very dense brown-gray sand - some gravel and silt (in-place soil)	-	

- continued -

ELEVATION
DEPTH
SAMPLE NO.
SAMPLE TYPE
SAMPLE DISTANCE
RECOVERY
UNCONFINED COMPRESSIVE STRENGTH TONS/FT.²
1 2 3 4 5
PLASTIC LIMIT %
WATER CONTENT %
LIQUID LIMIT %
10 20 30 40 50
STANDARD PENETRATION
BLOWS/FT.
10 20 30 40 50
*
63
72
76
TASK Engineers, Inc.
BL 2

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDRY LINES BETWEEN SOIL TYPES. IN SITU, THE TRANSITION MAY BE GRADUAL

Figure G-7. Boring log - Hole # LA-2.



OWNER	LOG OF BORING NUMBER 2
PROJECT NAME LA	ARCHITECT-ENGINEER
SITE LOCATION	

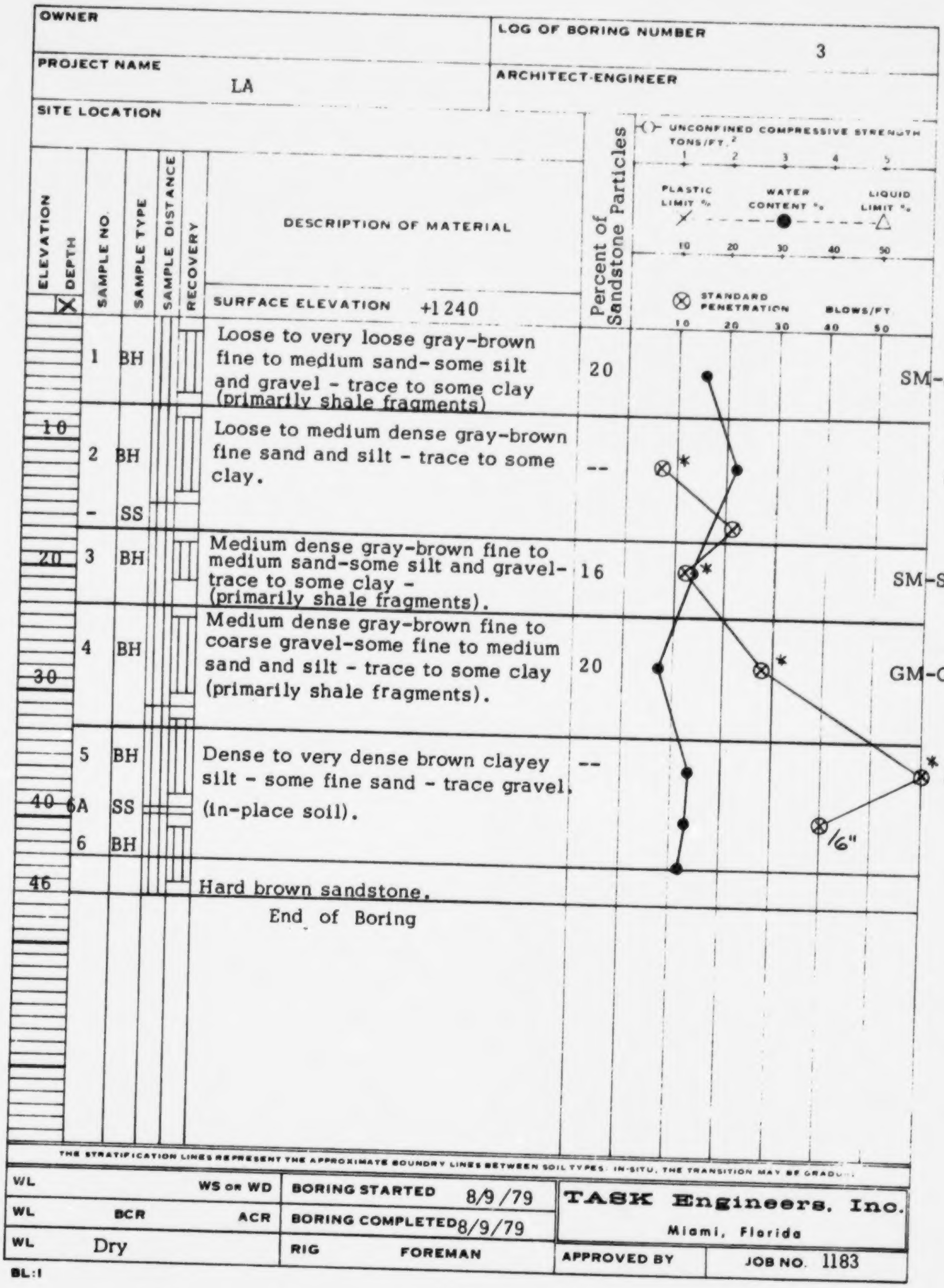
ELEVATION	DEPTH	SAMPLE NO	SAMPLE TYPE	SAMPLE DISTANCE	RECOVERY	DESCRIPTION OF MATERIAL SURFACE ELEVATION	Percent of Sandstone Particles	UNCONFINED COMPRESSIVE STRENGTH TONS/FT.² 1 2 3 4 5 PLASTIC LIMIT % ✕ — WATER CONTENT % ● — LIQUID LIMIT % △ 10 20 30 40 50 ⊗ STANDARD PENETRATION BLOWS/FT 10 20 30 40 50
						Continued		
		9	BH			Same as above		
79						Hard gray sandstone.		⊗*156
						End of Boring		

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES. IN SITU, THE TRANSITION MAY BE GRADUAL.

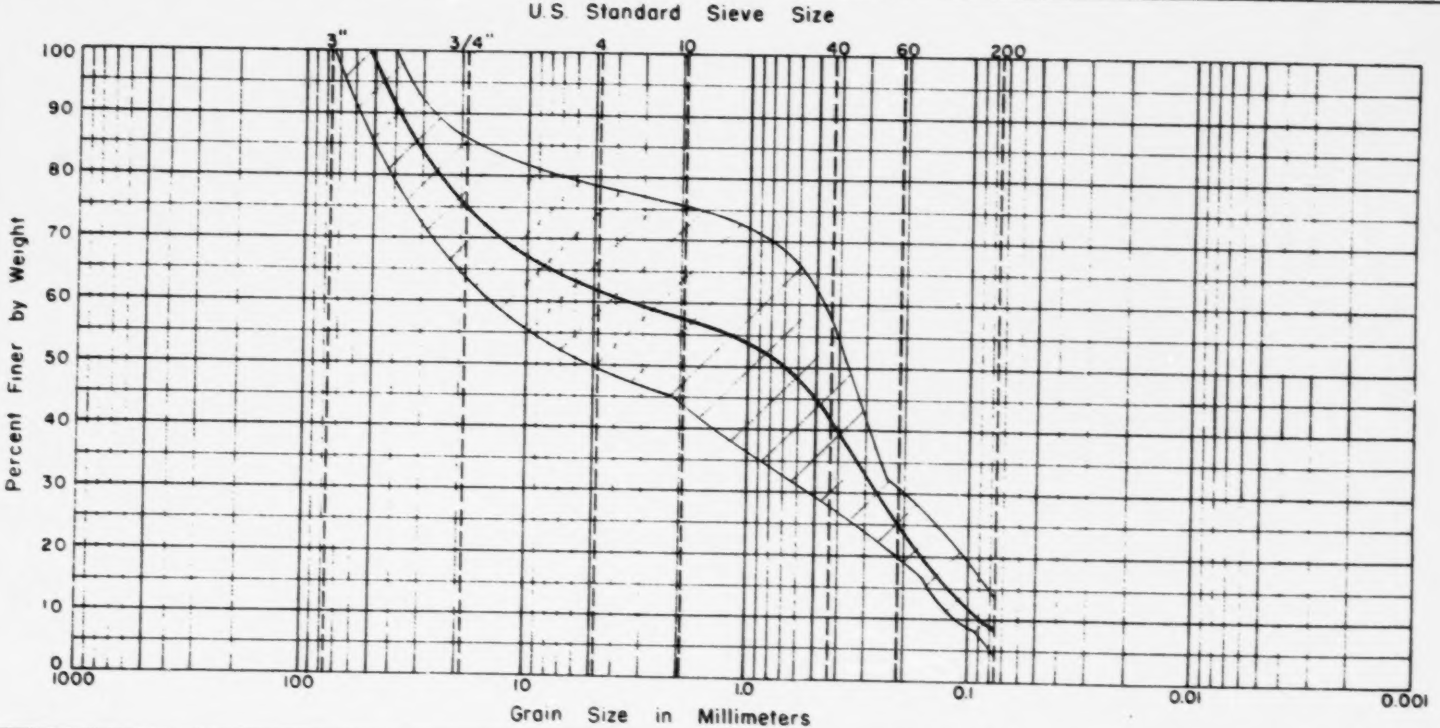
WL WS or WD	BORING STARTED 8/8/79	**TASK Engineers, Inc.** Miami, Florida	
WL BCR ACR	BORING COMPLETED 8/9/79		
WL 47 ft. after boring.	RIG FOREMAN	APPROVED BY	JOB NO. 1183

BL:I

Figure G-7 (continued). Boring log - Hole # LA-2.



GRADATION CURVES



Cobbles	Gravel		Sand			Silt - Clay
	Coarse	Fine	Coarse	Medium	Fine	

Form No. L015

Liquid Limit ________

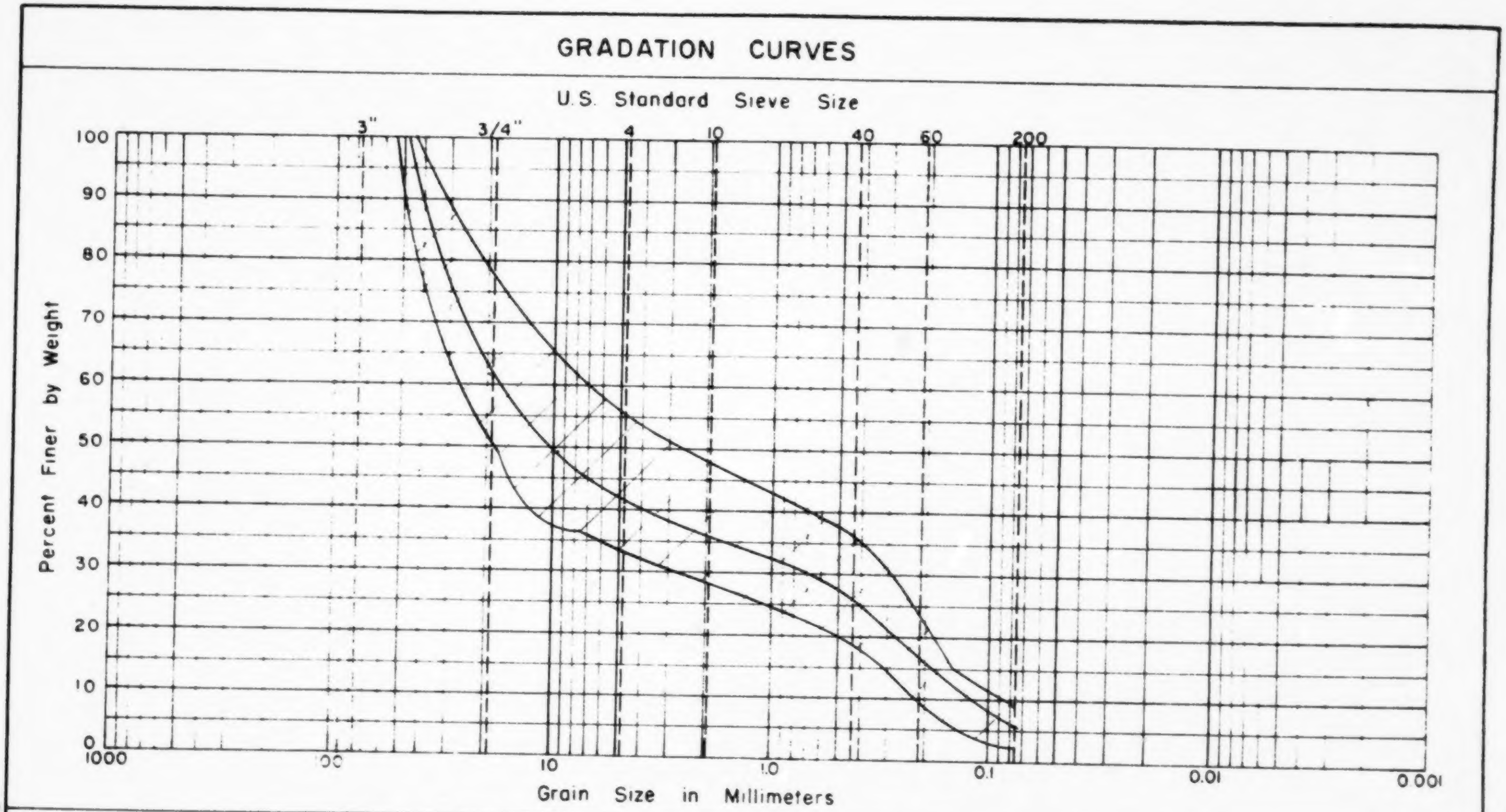
Plasticity Index ________

Class SP - SM

Boring	Sample	Depth	
BA - 1	Mean and Range	0 - 42.5	48% Sandstone

TASK Engineers, Inc.

Figure G-9. Gradation curve - Mean and range - Boring BA-1.

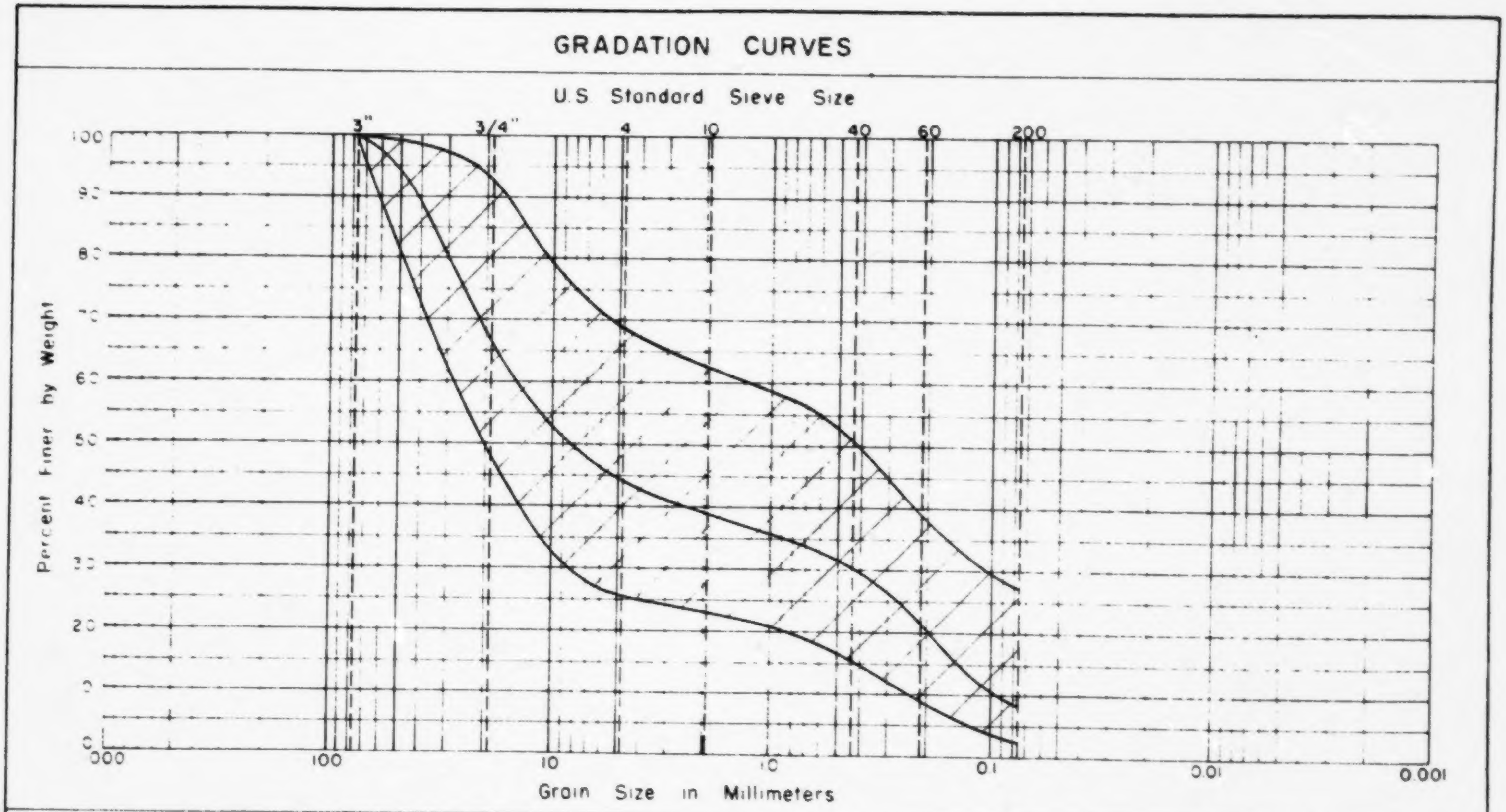


Cobbles	Gravel		Sand			Silt - Clay
	Coarse	Fine	Coarse	Medium	Fine	

Liquid Limit				
Plasticity Index				
Class		GP-GM		
Boring BA - 2	Sample Range and Mean	Depth 0 - 39	52% Sandstone	TASK Engineers, Inc.

Form No. L015

Figure G-10. Gradation curve - Mean and range - Boring BA-2.



Cobbles	Gravel		Sand			Silt - Clay
	Coarse	Fine	Coarse	Medium	Fine	

Liquid Limit

Plasticity Index

Class GP - GM

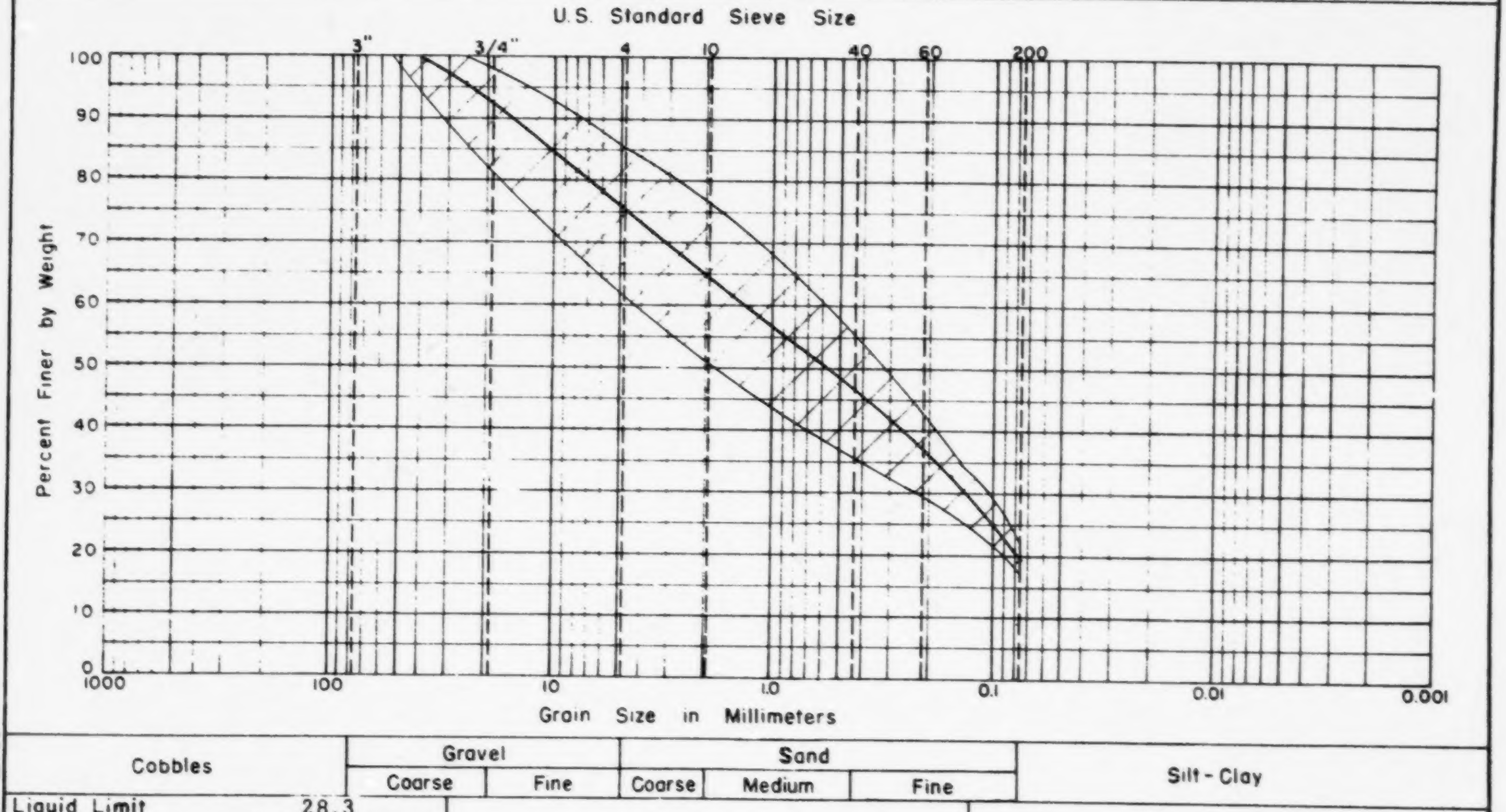
Boring	Sample	Depth	
BA - 3	Mean and Range	0 - 55	68% Sandstone

TASK Engineers, Inc.

Form No. L015

Figure G-11. Gradation curve - Mean and range - Boring BA-3.

GRADATION CURVES



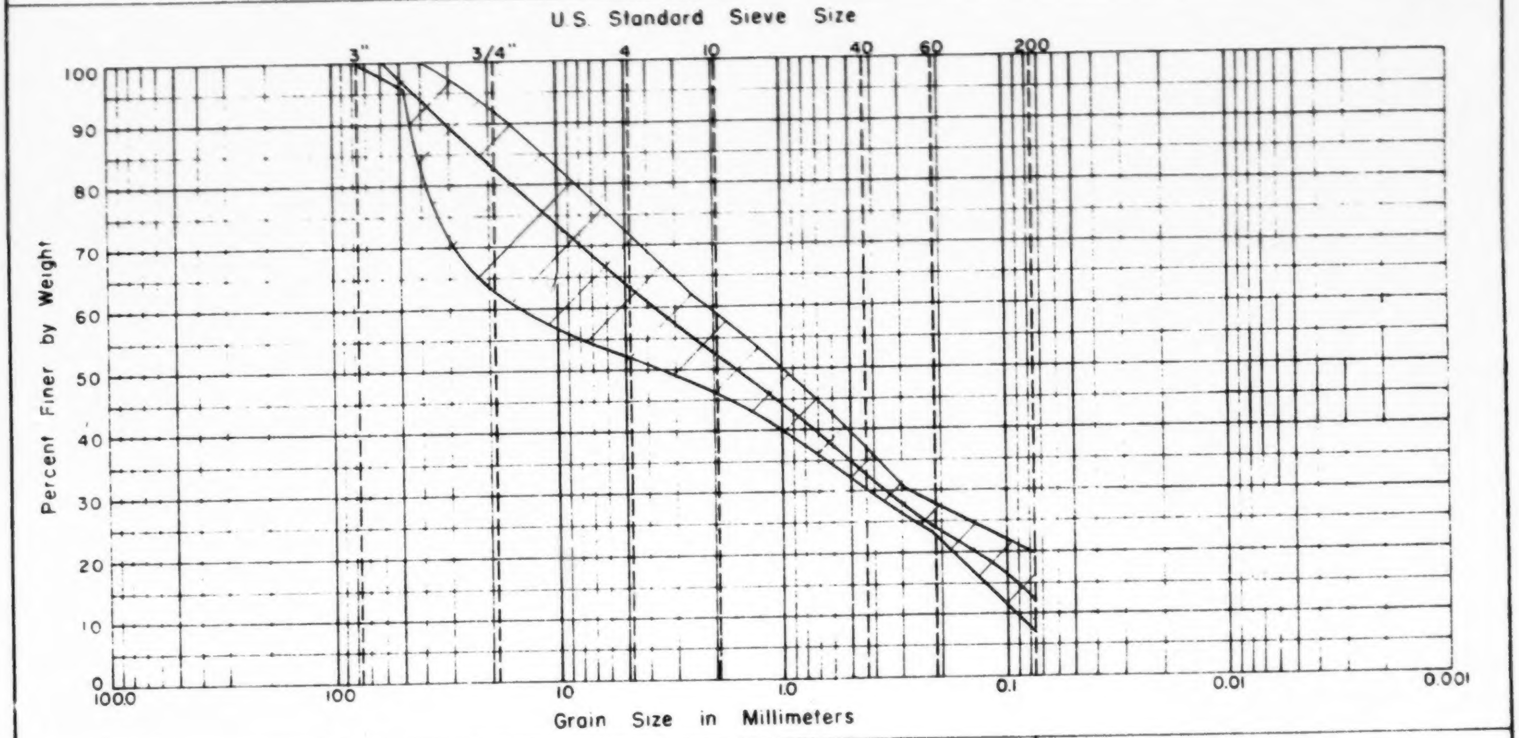
Form No. L015

Liquid Limit 28.3
Plasticity Index 6.9
Class SM - SC

Boring	Sample	Depth		
HA - 1	Mean and Range	0 - 39	9% Sandstone	TASK Engineers, Inc.

Figure G-12. Gradation curve - Mean and range - Boring HA-1.

GRADATION CURVES



Cobbles	Gravel		Sand			Silt - Clay
	Coarse	Fine	Coarse	Medium	Fine	

Liquid Limit ______

Plasticity Index ______

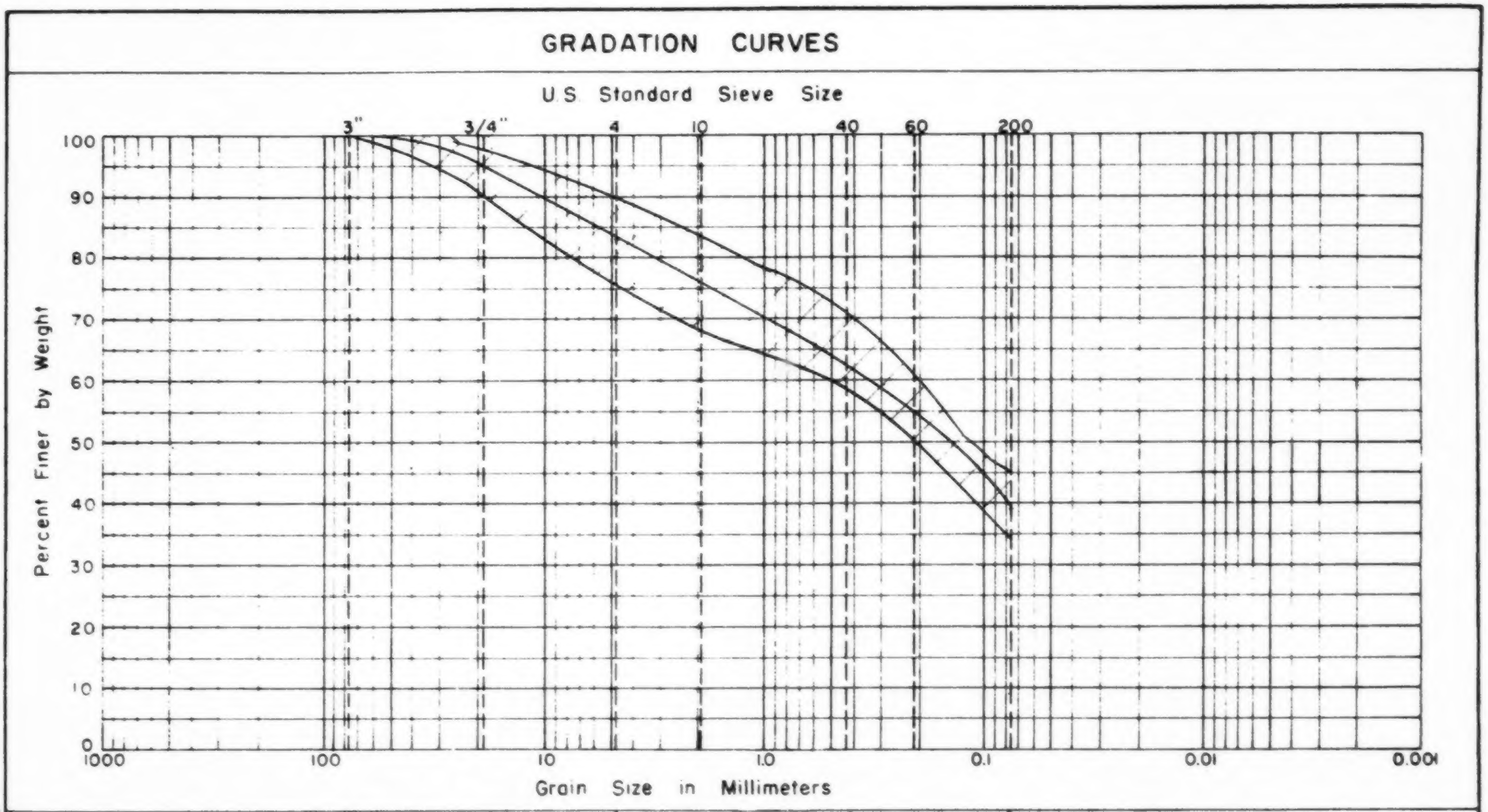
Class SP - SC

Boring	Sample	Depth	
HA - 2	Mean and Range	0 - 31	2% Sandstone

TASK Engineers, Inc.

Form No. L015

Figure G-13. Gradation curve - Mean and range - Boring HA-2.



Cobbles	Gravel		Sand			Silt - Clay
	Coarse	Fine	Coarse	Medium	Fine	

Form No. L015

Liquid Limit ______

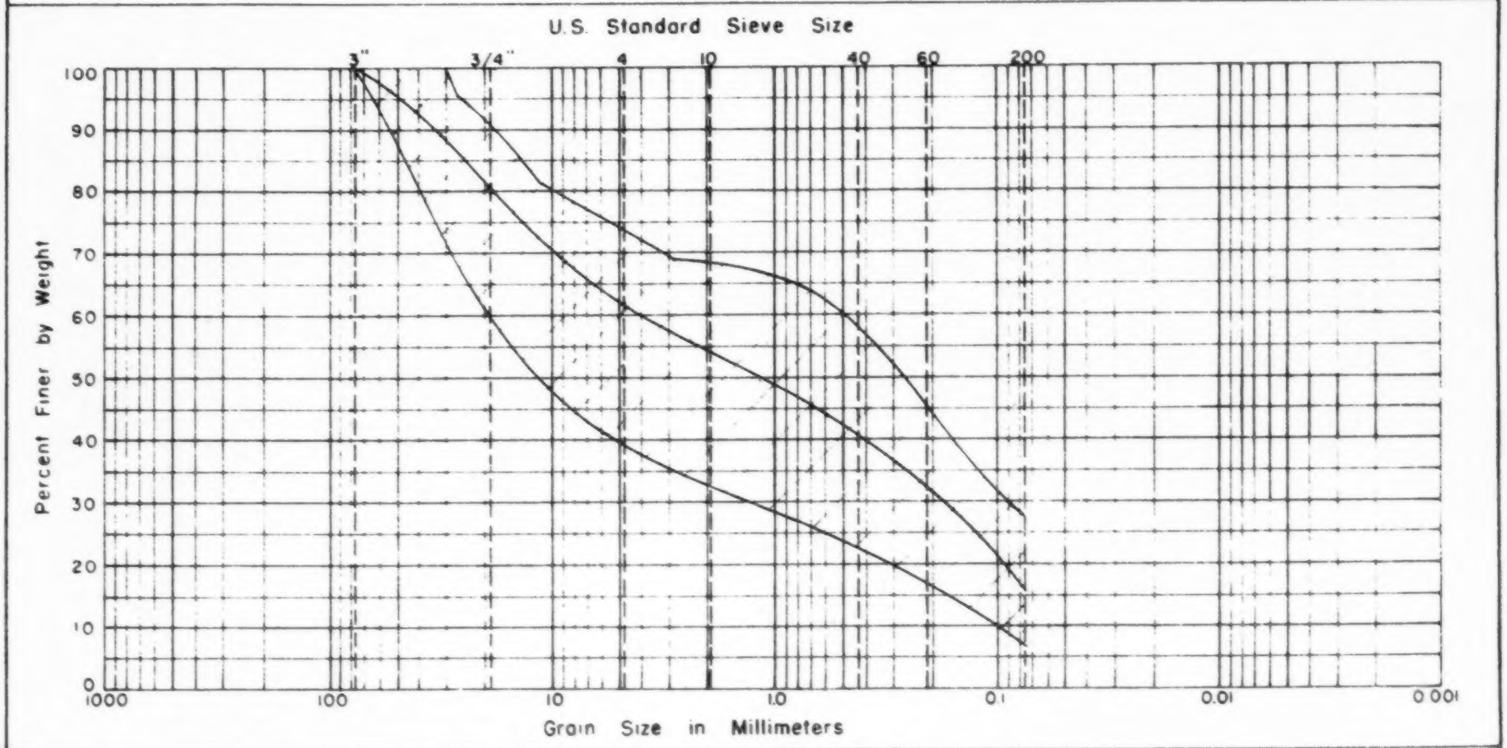
Plasticity Index ______

Class SM - SC

Boring	Sample	Depth		
LA - 1	Range and Mean	0 - 55	16% Sandstone	TASK Engineers, Inc.

Figure G-14. Gradation curve - Mean and range - Boring LA-1.

GRADATION CURVES



Cobbles	Gravel		Sand			Silt - Clay
	Coarse	Fine	Coarse	Medium	Fine	

Liquid Limit ______

Plasticity Index ______

Class SM

Boring	Sample	Depth
LA - 2	Mean and Range	0 - 63

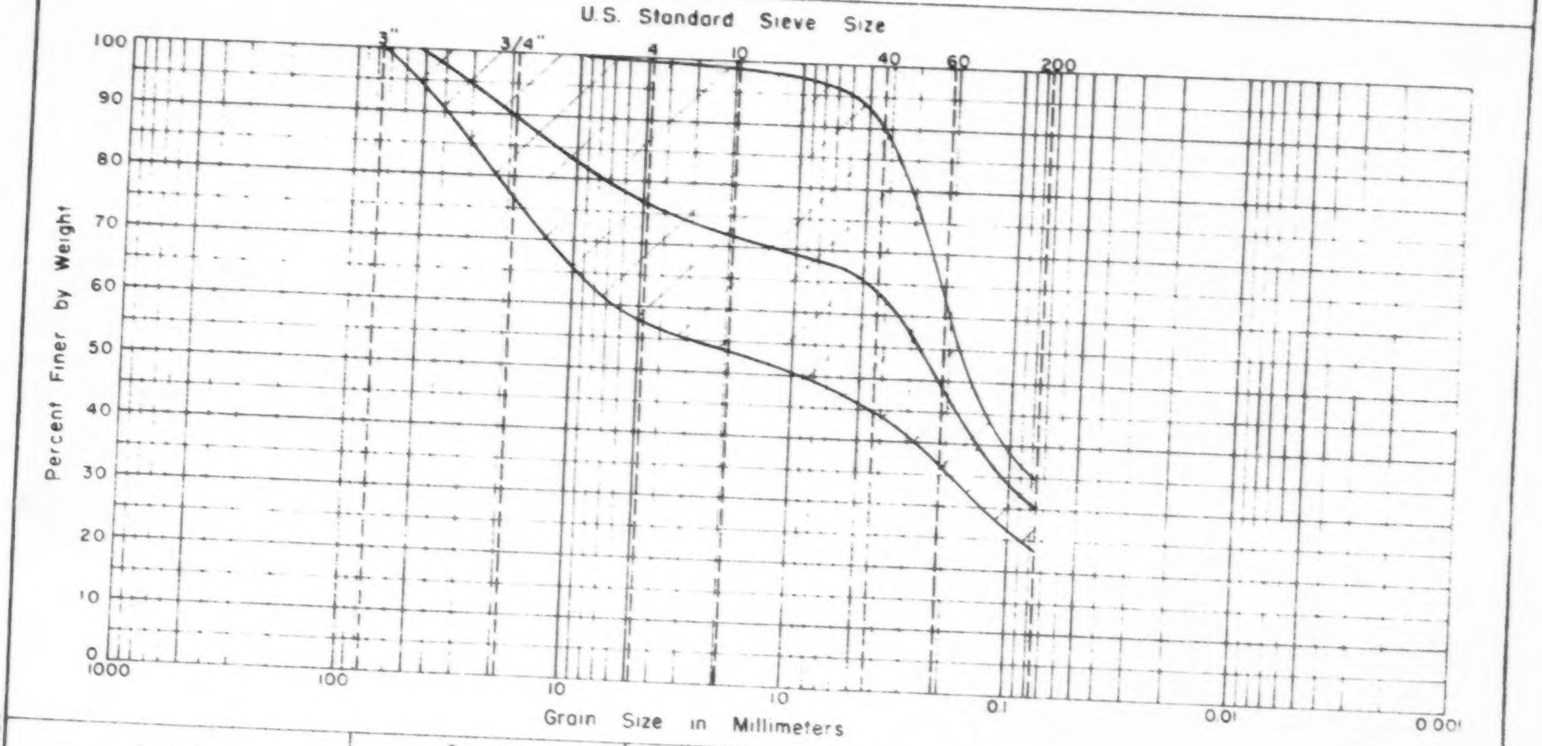
21% Sandstone

TASK Engineers, Inc.

Form No. L015

Figure G-15. Gradation curve - Mean and range - Boring LA-2.

GRADATION CURVES



Cobbles	Gravel		Sand			Silt - Clay
	Coarse	Fine	Coarse	Medium	Fine	

Liquid Limit ______

Plasticity Index ______

Class SM - SC

Boring	Sample	Depth		
LA - 3	Range and Mean	0 - 31	20% Sandstone	TASK Engineers, Inc.

Form No. L015

Figure G-16. Gradation curve - Mean and range - Boring LA-3.

BY
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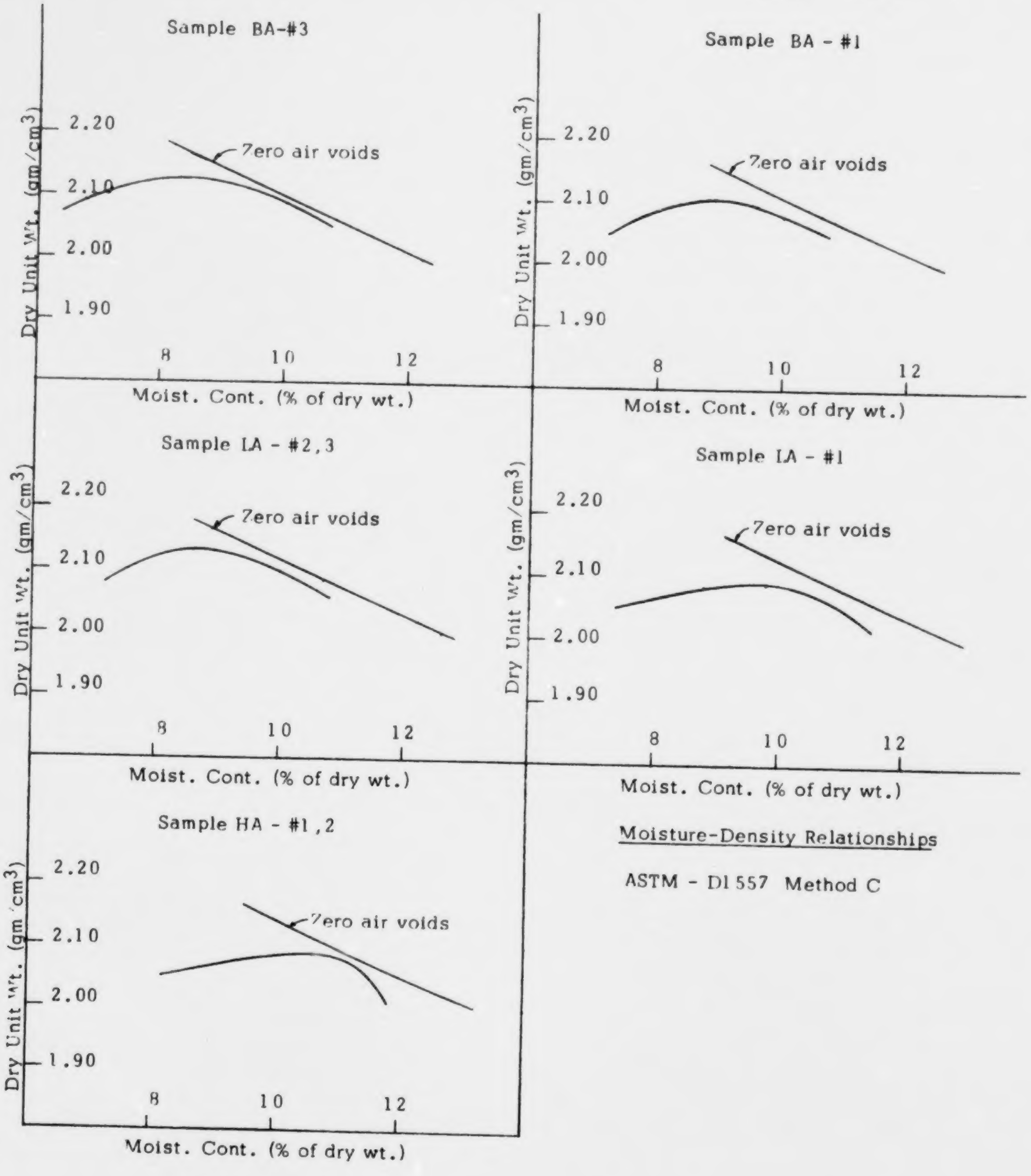
SUBJECT H O H HILLS
SHEET NO. 1 OF 1
CHKD. BY
DATE
JOB NO. 1183



Moisture-Density Relationships

ASTM - D1557 Method C

Figure G-17. Moisture density relationships.

APPENDIX H
SUSENDED PARTICULATE AND DUSTFALL DATA

TABLE H-1. SUSPENDED PARTICULATE HIGH-VOLUME SAMPLER DATA FOR SURFACE MINE #1: DRILLING-OVERBURDEN REMOVAL-COAL LOADING

Air temperature (°C)	(°F)	Wind speed (m/sec)	(ft/sec)	Percent cloud cover	Stability class	Distance: source to receptor (m)	(ft)	Total particulate weight (g)	Total air circulated (m^3)	Particulate concentration ($\mu g/m^3$)	Particulate concentration @ standard conditions* ($\mu g/m^3$)
20	68	2.2	7.1	0	A	46	150	0.00716	22.1	324.0	328.5
20	68	3.6	11.8	20	B	36	120	0.02266	22.1	1025.3	1041.0
21	70	3.1	10.1	10	B	36	120	0.01786	25.5	700.4	713.5
20	68	5.1	16.9	40	C	61	200	0.00381	9.2	414.1	419.9
23	73	4.7	15.4	40	C	24	80	0.00833	20.4	408.3	418.2
24	75	2.4	7.9	85	C	46	150	0.00604	10.6	569.8	585.6
18	64	1.6	5.1	10	A	30	100	0.01299	12.3	1056.1	1067.8
19	66	0.9	2.9	5	A	46	150	0.00745	8.5	876.5	889.3
19	66	0.9	2.9	5	A	30	100	0.00162	10.2	158.8	160.5
21	70	5.1	16.9	30	C	15	50	0.01809	12.7	1424.4	1449.1
20	68	2.1	6.8	98	B	23	75	0.00366	22.1	165.6	166.3
20	68	1.8	5.9	98	B	23	75	0.00506	22.1	229.0	230.0
18	64	3.1	10.1	95	C	46	150	0.01130	14.7	768.7	775.2

*298°K, 760 mm Hg (Smith _et al_, 1978)

TABLE H-2. SUSPENDED PARTICULATE HIGH-VOLUME SAMPLER DATA FOR SURFACE MINE #1: REGRADING

Air temperature (°C)	Air temperature (°F)	Wind speed (m/sec)	Wind speed (ft/sec)	Percent cloud cover	Stability class	Distance: source to receptor (m)	Distance: source to receptor (ft)	Total particulate weight (g)	Total air circulated (m^3)	Particulate concentration (ug/m^3)	Particulate concentration @ standard conditions* (µg/m^3)
21	70	6.2	20.3	40	D	30	100	0.02489	23.0	1082.2	1096.5
23	73	3.1	10.1	0	B	30	100	0.02199	18.7	1176.0	1206.2
24	75	3.3	11.0	0	B	46	150	0.00443	11.0	402.7	400.8
17	63	3.1	10.1	40	D	91	300	0.00350	10.2	343.1	338.8
18	64	3.1	10.1	30	B	46	150	0.00503	12.3	409.0	411.3

*298°K, 760mm Hg (Smith *et al*, 1978)

TABLE H-3. SUSPENDED PARTICULATE HIGH-VOLUME SAMPLER DATA FOR SURFACE MINE #1: RECLAIMED AREAS

Air temperature (°C)	Air temperature (°F)	Wind speed (m/sec)	Wind speed (ft/sec)	Percent cloud cover	Stability class	Distance: source to receptor (m)	Distance: source to receptor (ft)	Total particulate weight (g)	Total air circulated (m^3)	Particulate concentration (µg/m^3)	Particulate concentration @ standard conditions* (µg/m^3)
8	46	3.6	11.8	50	B	803	2640	0.00930	174.2	53.3	49.7
8	46	3.6	11.8	50	B	401	1320	0.00957	26.7	358.4	334.4
8	46	0.9	2.9	50	A	401	1320	0.01003	73.3	136.8	128.0
8	46	3.6	11.8	50	B	401	1320	0.00972	24.2	401.7	375.8
8	46	3.6	11.8	50	B	401	1320	0.00906	70.8	128.0	119.8
9	48	2.7	8.8	50	B	803	2640	0.01160	162.8	71.3	67.1
8	46	2.7	8.8	75	C	401	1320	0.01082	25.7	421.0	395.0
8	46	2.7	8.8	75	C	401	1320	0.01081	50.5	214.1	200.8
8	46	2.7	8.8	75	C	803	2640	0.00922	180.7	51.0	47.8
6	43	6.7	22.1	75	C	401	1320	0.00901	39.4	228.7	213.3
6	43	6.7	22.1	75	C	803	2640	0.00751	82.3		85.1
6	43	1.8	5.9	50	B	803	2640	0.01127	147.0	76.7	71.1

(continued)

TABLE H-3. (continued)

Air Temperature (°C)	Air Temperature (°F)	Wind speed (m/sec)	Wind speed (ft/sec)	Percent cloud cover	Stability class	Distance: source to receptor (m)	Distance: source to receptor (ft)	Total particulate weight (g)	Total air circulated (m^3)	Particulate concentration ($\mu g/m^3$)	Particulate concentration @ standard conditions* ($\mu g/m^3$)
6	43	1.8	5.9	50	B	401	1320	0.00827	46.5	177.9	164.8
6	43	1.8	5.9	50	B	401	1320	0.00875	24.0	364.6	337.8
12	54	0.9	2.9	10	A	401	2640	0.00912	145.7	62.6	59.2
12	54	0.9	2.9	10	A	803	1320	0.00916	55.4	165.3	156.4
12	54	0.9	2.9	10	A	401	1320	0.00825	23.8	346.6	328.0

*298°K, 760mm Hg (Smith et al, 1978)

TABLE H-4. SUSPENDED PARTICULATE HIGH-VOLUME SAMPLER DATA FOR SURFACE MINE #2: DRILLING-OVERBURDEN REMOVAL-COAL LOADING

Air temperature		Wind speed		Percent cloud cover	Stability class	Distance: source to receptor		Total particulate weight (g)	Total air circulated (m^3)	Particulate concentration ($\mu g/m^3$)	Particulate concentration @ standard conditions* ($\mu g/m^3$)
(°C)	(°F)	(m/sec)	(ft/sec)			(m)	(ft)				
23	73	7.2	23.7	80	D	76	250	0.30670	10.2	30069.0	31836.0
24	75	6.7	22.1	90	D	15	50	0.08683	11.9	7296.6	7751.5
18	64	9.2	30.4	50	D	46	150	0.12934	34.0	3804.1	3926.6
22	72	6.2	20.3	40	D	30	100	0.29358	24.4	12032.0	12642.8
20	68	2.2	7.4	40	B	30	100	0.11752	21.2	5543.4	5842.4
24	75	6.7	22.1	30	C	46	150	0.04188	10.2	4106.0	4380.4
17	63	6.2	20.3	50	D	15	50	0.31014	13.6	22804.0	23687.9
17	63	2.2	7.4	50	B	30	100	0.14379	16.1	8931.1	9236.3
12	54	2.5	8.1	75	C	23	75	0.08095	26.8	3020.5	3079.2
16	61	3.1	10.1	80	C	15	50	0.25733	15.6	16496.0	17052.4
15	59	2.6	8.5	90	C	15	50	0.26758	16.6	16119.0	16605.0
20	68	3.1	10.1	5	A	15	50	0.32937	14.9	22105.0	23166.8
18	64	0.9	2.9	5	A	15	50	0.28452	10.2	27894.0	28872.3
18	64	0.9	2.9	5	A	46	150	0.03332	5.5	6058.0	6270.5

*298°K, 760mm Hg (Smith et al, 1978)

TABLE H-5. SUSPENDED PARTICULATE HIGH-VOLUME SAMPLER DATA FOR SURFACE MINE #2: REGRADING

Air temperature (°C)	Air temperature (°F)	Wind speed (m/sec)	Wind speed (ft/sec)	Percent cloud cover	Stability class	Distance: source to receptor (m)	Distance: source to receptor (ft)	Total particulate weight (g)	Total air circulated (m^3)	Particulate concentration ($\mu g/m^3$)	Particulate concentration ê standard conditions* ($\mu g/m^3$)
22	72	0.7	2.2	100	B	30	100	0.05158	15.3	3371.2	3557.2
21	70	6.7	21.9	30	D	30	100	0.05457	15.3	3566.7	3766.6
8	46	1.5	5.0	50	A	30	100	0.06287	19.5	3224.1	3227.0
15	59	2.2	7.1	30	A	61	200	0.02263	20.4	1109.3	1139.5
10	50	2.0	6.6	25	A	30	100	0.04224	20.5	2060.5	2077.0
15	59	2.9	9.6	90	C	30	100	0.08132	19.3	4213.5	4334.5
14	57	3.1	10.1	20	B	15	50	0.12917	11.9	10855.0	11081.3
14	57	3.1	10.1	20	B	30	100	0.09949	14.7	6768.0	6909.1
17	63	5.3	17.5	5	C	30	100	0.22104	19.5	11335.0	11757.8
17	63	5.3	17.5	5	C	30	100	0.13209	11.5	11486.0	11914.5

*298°K, 760mm Hg (Smith et al, 1978)

TABLE H-6. SUSPENDED PARTICULATE HIGH-VOLUME SAMPLER DATA FOR SURFACE MINE #2: HAUL ROADS

Air temperature (°C)	Air temperature (°F)	Wind speed (m/sec)	Wind speed (ft/sec)	Percent cloud cover	Stability class	Distance: source to receptor (m)	Distance: source to receptor (ft)	Total particulate weight (g)	Total air circulated (m^3)	Particulate concentration ($\mu g/m^3$)	Particulate concentration @ standard conditions* ($\mu g/m^3$)
23	73	6.2	20.3	40	D	36	120	0.27391	29.3	9348.5	9656.4
17	63	3.1	10.1	60	B	30	100	0.05129	22.3	2300.0	2346.3
21	70	3.1	10.1	5	B	8	25	0.22459	8.5	26422.0	27515.5
21	70	3.1	10.3	5	A	15	50	0.25530	11.0	23209.0	24169.6

*298°K, 760mm Hg (Smith et al, 1978)

TABLE H-7. SUSPENDED PARTICULATE HIGH-VOLUME SAMPLER DATA FOR SURFACE MINE #2: RECLAIMED AREAS

Air temperature (°C)	(°F)	Wind speed (m/sec)	(ft/sec)	Percent cloud cover	Stability class	Distance: source to receptor (m)	(ft)	Total particulate weight (g)	Total air circulated (m^3)	Particulate concentration ($\mu g/m^3$)	Particulate concentration @ standard conditions* ($\mu g/m^3$)
12	54	0.9	2.9	10	A	803	2640	0.01118	160.7	69.6	65.9
10	50	2.7	8.8	10	B	401	1320	0.00825	32.4	254.6	239.3
10	50	2.7	8.8	10	B	401	1320	0.00821	41.7	196.9	185.0
10	50	2.7	8.8	10	B	401	1320	0.00982	18.1	542.5	509.8
10	50	2.7	8.8	10	B	803	2640	0.01053	153.0	68.8	64.7
10	50	2.7	8.8	10	B	401	1320	0.00825	54.6	151.1	142.0
1	34	0.9	2.9	10	A	803	2640	0.01350	146.4	92.2	83.9
1	34	0.9	2.9	10	A	401	1320	0.01307	55.8	234.2	213.1
1	34	0.9	2.9	10	A	401	1320	0.01301	23.8	546.6	497.3
10	50	2.7	8.8	10	B	803	2640	0.00821	116.6	70.4	66.2
13	55	4.5	14.7	10	B	401	1320	0.01062	56.9	186.6	177.5
13	55	2.7	8.8	10	B	401	1320	0.01075	18.0	597.2	568.0
10	50	2.7	8.8	10	B	401	1320	0.00929	15.2	611.2	575.1

(continued)

TABLE H-7. (continued)

Air temperature (°C)	Air temperature (°F)	Wind speed (m/sec)	Wind speed (ft/sec)	Percent cloud cover	Stability class	Distance: source to receptor (m)	Distance: source to receptor (ft)	Total particulate weight (g)	Total air circulated (m^3)	Particulate concentration ($\mu g/m^3$)	Particulate concentration @ standard conditions* ($\mu g/m^3$)
13	55	2.7	8.8	10	B	401	1320	0.00928	45.3	204.9	194.9
13	55	4.5	14.7	10	B	803	2640	0.00494	129.0	38.3	36.4
10	50	2.7	8.8	10	B	401	1320	0.00419	26.5	158.1	149.2
10	50	2.7	8.8	10	B	401	1320	0.00256	14.4	177.8	167.7
10	50	2.7	8.8	10	B	803	2640	0.00978	191.6	51.0	48.1

*298°K, 760mm Hg (Smith *et al*, 1978)

TABLE H-8. SUSPENDED PARTICULATE HIGH-VOLUME SAMPLER DATA FOR SURFACE MINE #3: DRILLING-OVERBURDEN REMOVAL-COAL LOADING

Air temperature (°C)	(°F)	Wind speed (m/sec)	(ft/sec)	Percent cloud cover	Stability class	Distance: source to receptor (m)	(ft)	Total particulate weight (g)	Total air circulated (m^3)	Particulate concentration ($\mu g/m^3$)	Particulate concentration @ standard conditions* ($\mu g/m^3$)
28	82	1.6	5.1	10	A	30	100	0.02832	47.1	601.3	661.3
28	82	1.6	5.1	10	A	30	100	0.00703	7.9	889.8	977.2
30	86	0.9	2.9	10	A	15	50	0.01865	15.0	1243.3	1307.6
27	81	0.9	3.1	10	A	15	50	0.09354	22.0	4251.8	4640.6
19	66	2.2	7.3	10	A	30	100	0.03315	41.0	808.6	862.7
21	70	2.7	8.8	10	A	30	100	0.09734	19.1	5096.3	5474.5
23	73	2.9	9.5	10	A	15	50	0.06641	55.2	1203.1	1299.3
22	72	2.7	8.8	10	A	30	100	0.18597	29.4	6325.5	6818.0
22	72	2.9	9.5	10	A	15	50	0.06414	24.1	2661.4	2872.7
24	75	10.7	35.2	10	C	30	100	0.07093	23.4	3031.2	3294.1
25	77	3.8	12.5	10	B	15	50	0.01957	21.3	918.8	1001.8
25	77	1.1	3.7	10	A	30	100	0.03630	18.4	1972.8	2151.1
24	75	2.5	8.1	10	A	15	50	0.05480	27.9	1964.1	2134.4

(continued)

TABLE H-8. (continued)

Air temperature (°C)	Air temperature (°F)	Wind speed (m/sec)	Wind speed (ft/sec)	Percent cloud cover	Stability class	Distance: source to receptor (m)	Distance: source to receptor (ft)	Total particulate weight (g)	Total air circulated (m^3)	Particulate concentration ($\mu g/m^3$)	Particulate concentration @ standard conditions ($\mu g/m^3$)
27	81	0.9	2.9	10	A	15	50	0.01395	37.5	372.0	408.3
27	81	1.1	3.7	10	A	30	100	0.03909	20.2	1935.1	2127.2
27	81	1.6	5.1	10	A	15	50	0.06061	31.0	1955.2	2149.3
27	81	0.9	2.9	10	A	15	50	0.03059	41.4	738.9	813.4
28	82	0.9	2.9	10	A	30	100	0.05915	9.4	6292.6	6950.4
27	81	2.2	7.3	10	A	15	50	0.05512	22.7	2428.2	2673.1
27	81	0.9	2.9	10	A	15	50	0.00593	17.0	348.8	386.8
24	75	9.8	32.3	40	D	15	50	0.04856	23.8	2040.3	2223.6
25	77	8.9	29.4	50	D	15	50	0.01690	21.2	797.2	870.5
27	81	2.5	8.1	75	C	15	50	0.03982	43.8	909.1	999.4
27	81	2.5	8.1	75	C	15	50	0.04367	36.8	1186.7	1314.0
25	77	2.5	8.1	75	C	15	50	0.01783	32.2	553.7	609.0
14	57	4.0	13.2	50	C	15	50	0.04427	22.9	1933.2	2027.2

(continued)

TABLE H-8. (continued)

Air temperature (°C)	Air temperature (°F)	Wind speed (m/sec)	Wind speed (ft/sec)	Percent cloud cover	Stability class	Distance: source to receptor (m)	Distance: source to receptor (ft)	Total particulate weight (g)	Total air circulated (m³)	Particulate concentration (µg/m³)	Particulate concentration @ standard conditions* (µg/m3)
15	59	6.7	22.0	50	D	61	200	0.03786	42.5	890.8	936.0
15	59	6.7	22.0	50	D	15	50	0.08258	34.8	2373.0	2493.5
15	59	6.7	22.0	50	D	61	200	0.09072	53.9	1683.1	1766.0
16	61	6.7	22.0	50	D	61	200	0.06865	49.2	1395.3	1469.1
16	61	2.2	7.3	50	D	15	50	0.06251	30.6	2042.8	2151.0
27	81	6.7	22.0	75	D	61	200	0.05416	48.9	1107.6	1210.6
27	81	6.7	22.0	75	D	15	50	0.08764	36.5	2401.1	2524.4

*298°K, 760mm Hg (Smith *et al*, 1978)

TABLE H-9. SUSPENDED PARTICULATE HIGH-VOLUME SAMPLER DATA FOR SURFACE MINE #3: REGRADING

Air temperature (°C)	(°C)	Wind speed (m/sec)	(ft/sec)	Percent cloud cover	Stability class	Distance: source to receptor (m)	(ft)	Total particulate weight (g)	Total air circulated (m^3)	Particulate concentration ($\mu g/m^3$)	Particulate concentration @ standard conditions* ($\mu g/m^3$)
28	82	1.6	5.1	10	A	61	200	0.00801	27.2	294.5	323.9
28	82	0.9	2.9	10	A	15	50	0.02458	32.6	754.0	825.7
20	68	2.2	7.3	10	A	30	100	0.02666	15.3	1742.5	1865.4
23	73	2.5	8.1	10	A	30	100	0.11278	20.4	5528.4	5971.0
22	72	2.5	8.1	10	C	30	100	0.05340	12.0	4450.0	4803.4
13	55	5.4	17.6	50	C	61	200	0.04657	31.0	1502.3	1569.9
16	61	6.7	22.0	50	C	15	50	0.12742	30.5	4177.7	4398.8

*298°K, 760mm Hg (Smith et al, 1978)

TABLE H-10. SUSPENDED PARTICULATE HIGH-VOLUME SAMPLER DATA FOR SURFACE MINE #3: HAUL ROADS

Air temperature (°C)	Air temperature (°F)	Wind speed (m/sec)	Wind speed (ft/sec)	Percent cloud cover	Stability class	Distance: source to receptor (m)	Distance: source to receptor (ft)	Total particulate weight (g)	Total air circulated (m^3)	Particulate concentration ($\mu g/m^3$)	Particulate concentration @ standard conditions* ($\mu g/m^3$)
24	75	6.7	22.0	50	D	6	20	0.10878	9.4	11572.0	12611.8
25	77	6.7	22.0	75	D	6	20	0.02956	12.5	2364.8	2582.3
25	77	8.9	29.4	75	D	6	20	0.07321	4.7	15577.0	17009.0
27	81	6.7	22.0	75	D	6	20	0.10235	5.1	20069.0	22062.0
27	81	6.7	22.0	75	D	6	20	0.08145	14.2	5736.0	6305.4
25	77	6.7	22.0	75	D	6	20	0.05105	16.4	3112.8	3423.6
25	77	6.7	22.0	75	D	6	20	0.10547	5.1	20680.0	22745.0
27	81	3.6	11.7	100	C	6	20	0.00621	2.8	2218.0	2466.6

*298°K, 760mm Hg (Smith et al, 1978)

TABLE H-11. SUSPENDED PARTICULATE HIGH-VOLUME SAMPLER DATA FOR SURFACE MINE #3: RECLAIMED AREAS

Air temperature (°C)	Air temperature (°F)	Wind speed (m/sec)	Wind speed (ft/sec)	Percent cloud cover	Stability class	Distance: source to receptor (m)	Distance: source to receptor (ft)	Total particulate weight (g)	Total air circulated (m^3)	Particulate concentration ($\mu g/m^3$)	Particulate concentration @ standard conditions* ($\mu g/m^3$)
20	68	2.9	9.5	50	B	914	3000	0.01095	24.9	439.8	465.8
19	66	2.9	9.5	10	A	914	3000	0.01527	164.0	93.1	98.6
21	70	2.9	9.5	10	A	914	3000	0.00385	38.5	100.0	106.7
24	75	0.9	2.9	10	A	914	3000	0.00475	24.8	191.5	207.8
24	75	0.9	2.9	10	A	914	3000	0.00526	52.7	99.8	108.3
29	84	0.9	2.9	10	A	914	3000	0.00942	34.0	277.1	306.2
17	62	2.7	8.8	75	C	1828	6000	0.00568	20.2	281.2	297.5
17	62	2.7	8.8	75	C	1828	6000	0.00799	48.4	165.1	174.7
25	77	0.9	2.9	50	B	1828	6000	0.00582	60.5	96.2	104.6
25	77	0.9	2.9	50	B	1828	6000	0.00842	27.2	309.6	336.6
26	79	1.6	5.1	75	C	1828	6000	0.00990	20.4	485.3	528.0

(continued)

TABLE H-11 (continued)

Air temperature (°C)	Air temperature (°F)	Wind speed (m/sec)	Wind speed (ft/sec)	Percent cloud cover	Stability class	Distance: source to receptor (m)	Distance: source to receptor (ft)	Total particulate weight (g)	Total air circulated (m^3)	Particulate concentration ($\mu g/m^3$)	Particulate concentration @ standard conditions* ($\mu g/m^3$)
25	77	0.9	2.9	50	B	1828	6000	0.00734	52.7	139.3	151.5
26	79	0.9	2.9	75	B	1828	6000	0.01441	56.1	256.9	280.3
26	79	0.9	2.9	75	B	1828	6000	0.00792	27.2	291.2	317.7
23	73	4.7	15.4	10	B	914	3000	0.00819	56.1	146.0	156.1
23	73	4.7	15.4	10	B	914	3000	0.00472	56.4	83.7	89.5

*298°K, 760mm Hg (Smith et al, 1978)

TABLE H-12. DUSTFALL DATA FROM BUCKET COLLECTION AT MINE #1

Day	Bucket	Distance: source to receptor (m)	(ft)	Total dustfall (g)	(g/m^2)
1	A	249	820	0.00700	0.25455
	B	90	295	0.05400	1.96364
	C	179	590	0.06300	2.29091
	D	149	490	0.08900	3.23636
	E	274	900	0.00600	0.21818
	F	274	900	0.06800	2.47273
2	A	249	820	0.00300	0.10909
	B	90	295	0.06800	2.47273
	C	179	590	0.05100	1.85455
	D	149	490	0.06700	2.43636
	E	274	900	0.05000	1.81818
	F	274	900	0.00400	0.14545
3	A	249	820	0.02600	0.94545
	B	90	295	0.03224	1.17236
	C	179	590	0.08457	3.07527
	D	149	490	0.00800	0.29091
	E	274	900	0.10000	3.63636
	F	274	900	0.06500	2.36364
4	A	249	820	0.00929	0.33782
	B	90	295	0.04080	1.48364
	C	179	590	0.01135	0.41273
	D	149	490	0.00967	0.35164
	E	274	900	0.06328	2.30109
	F	274	900	0.00912	0.33164
5	A	249	820	0.00890	0.32364
	B	90	295	0.05284	1.92145
	C	179	590	0.03106	1.12945
	D	149	490	0.11168	4.06109
	E	274	900	0.03352	1.21890
	F	274	900	0.01670	0.60727
6	C	179	590	0.01000	0.36364
	D	149	490	0.09900	3.60000
	E	274	900	0.07300	2.65455
	F	274	900	0.01300	0.47273
7	B	90	295	0.01180	0.42909
	C	179	590	0.01027	0.37345

TABLE H-13. DUSTFALL DATA FROM BUCKET COLLECTION AT MINE #2

Day	Bucket	Distance: source to receptor (m)	(ft)	Total dustfall (g)	(g/m^2)
1	A	122	400	0.01871	0.68036
	B	182	600	0.01457	0.52982
	C	730	2400	0.02017	0.73345
	D	775	2550	0.01648	0.59927
	E	775	2550	0.04369	1.58873
	F	730	2400	0.04678	1.70109
2	A	122	400	0.01523	0.55382
	B	182	600	0.01135	0.41273
	C	730	2400	0.01787	0.64982
	D	775	2550	0.01162	0.42255
	E	775	2550	0.02649	0.96327
	F	730	2400	0.01869	0.67964
3	A	122	400	0.01085	0.39455
	B	182	600	0.01647	0.59891
	C	730	2400	0.01632	0.59345
	D	775	2550	0.00960	0.34909
	E	775	2550	0.08780	3.19273
	F	730	2400	0.04186	1.52218
4	A	122	400	0.02377	0.86436
	B	182	600	0.03741	1.36036
	C	730	2400	0.02356	0.85673
	D	775	2550	0.01625	0.59091
	E	775	2550	0.03847	1.39891
	F	730	2400	0.02553	0.92836
5	A	122	400	0.01277	0.46436
	B	182	600	0.03261	1.18582
	C	730	2400	0.03725	1.35455
	D	775	2550	0.01877	0.68255
	E	775	2550	0.02355	0.85636
	F	730	2400	0.03765	1.36909
6	A	122	400	0.10207	3.71164
	B	182	600	0.06958	2.53018
	C	730	2400	0.02596	0.94400
	D	775	2550	0.00925	0.33636
	E	775	2550	0.01746	0.63491
	F	730	2400	0.02339	0.85055

(continued)

TABLE H-13. (continued)

Day	Bucket	Distance: source to receptor		Total dustfall	
		(m)	(ft)	(g)	(g/m^2)
7	A	122	400	0.04574	1.66327
	B	182	600	0.02952	1.07345
	C	730	2400	0.03920	1.42545
	D	775	2550	0.01787	0.64982
	E	775	2550	0.09747	3.54436
	F	730	2400	0.09755	3.54727
8	A	122	400	0.05329	1.93782
	B	182	600	0.01335	0.48545
	D	775	2550	0.01265	0.46000
	E	775	2550	0.02257	0.82072
	F	730	2400	0.01827	0.66436

TABLE H-14. DUSTFALL DATA FROM BUCKET COLLECTION AT MINE #4

Day	Bucket	Distance: source to receptor (m)	(ft)	Total dustfall (g)	(g/m^2)
1	A	23	75	0.05000	1.81818
	B	23	75	0.02100	0.76364
	C	23	75	0.10200	3.70909
	D	23	75	0.03200	1.16364
2	B	23	75	0.01800	0.65455
	C	23	75	0.01400	0.50909
	D	23	75	0.01500	0.54545
3	A	23	75	0.00200	0.07273
	C	23	75	0.04800	1.74545
	D	23	75	0.02000	0.72727